Proceedings of a Workshop on

COMPUTER AND INFORMATION SYSTEMS IN RESOURCES MANAGEMENT DECISIONS

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE AND COOPERATIVE STATE RESEARCH SERVICE

PREFACE

The format of this publication follows the agenda of the workshop.

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COMPUTER AND INFORMATION SYSTEMS IN RESOURCES MANAGEMENT DECISIONS

September 30, 1971

Compiled and Edited by
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U.S. Department of Agriculture
Forest Service
Cooperative State Research Service

Washington, D C. 20250
July 1972

FOREWORD

This workshop was held in Cleveland, Ohio as part of the 1971 National Convention of the Society of American Foresters. Aimed at every practicing forester, this program explored the role computers are able to play now in resource management operations and what we can expect in the next few years.

Three groups joined in developing and presenting the workshop program and accompanying computer exhibits of applications in resource management:

- The USDA Land Grant University Committee on Computer Use in Renewable Resources Management co-chaired by Robert N. Stone, and Kenneth D. Ware.

- The S.A.F. Group on Mensuration, Kenneth D. Ware, chairman, and Tommy R. Dell, vice-chairman.

- The Computer Exhibit Committee chaired by John W. Moser.

A number of people in these groups contributed generously of their time in arranging the program and in preparing these proceedings. The chairmen especially acknowledge the efforts of Jay M. Hughes, Cooperative State Research Service, Peter E. Dress, Pennsylvania State University and Carol A. Varva, Forest Service.

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OPENING REMARKS AND OVERVIEW

Robert N. Stone
Forest Service

Today, in six short hours, we will explore the current impact of computers on forestry, and related resource management and planning. You will have access to computer terminals able to aid you in forestry choices sooner than you may think. It is not too early to learn more about this fast moving computer technology and what it means in forest resource management. Aimed at every practicing forester, today's program will explore the role computers are able to play now in forestry operations and what we can expect in the next few years.

Two sessions have been designed, the morning program will look to the broader implications of computer technology and its changing impact on the forestry profession. The afternoon session will focus on what we are now doing to plan and implement forestry activities through computer applications.

Man, the tool user and machine builder has extended his natural capabilities in marvelous ways with devices of all kinds. The stirrup allowed man to ride at speeds three times faster than he could walk with reasonable assurance of staying on the horse. The auto multiplied travel speeds by a factor of 10. The jet airliner has since increased this 10 more times. Innumerable technical advances in engines and appliances could be noted that do things faster or better in a given period of time. Although few of these changes extend as much as several hundred times man's natural strength or capabilities they have changed the world and man himself.

The development of the modern auto spanned several decades. Think about the impact this machine has had on our lives. Contrast this with the startling abruptness of man's extended capabilities via the computer. The ability, for example, to calculate with widely available large computers is on the order of one million times that of a skilled mathematician working with pencil and pad. This extension of technology came about in only 20 years. It is little wonder that so few understand the potential of this capability, much less are able to effectively use it now.

One must look to communications, namely radio and telephone to find comparable multiples of performance. Now that computers and telecommunications are being welded, the joint extensions of man's capability to react and recall will expand by several orders of magnitude, available to all with the price. The technology is here now. How will we foresters use it? What can we now do with it?

The carefully selected experts you will see and hear today have some of the answers.

FUTURE USES OF COMPUTERS IN ENVIRONMENTAL MANAGEMENT

Robert H. Giles, Jr.
Virginia Polytechnic Institute and State University

Today I have the privilege of exercising my obsession with humanizing the future. I assume that this audience, of all the people in the world, knows best the frailness of our planet, comprehends best the ponderous plodding of natural ecological succession, and senses best the perils of an impeded global production system - whether of cellulose or of protein.

I assume also that you will accept my basic tenet that we are now in the midst of an environmental crisis rotted in population growth. Accepting my tenet, I assume you also find inconsistent a life lived while in a rocking chair on the brink of a catastrophy. I have lowered my priorities for long term and basic research now that I see a calamity aborning. Research to produce answers to questions which will be asked tomorrow is unsatisfying when I find tomorrow in doubt. I am convinced that when resource managers themselves practice birth control, when they assign their research priorities as if a population crisis were pending, when they leap to manipulate (conventionally or not) habitats, populations, and man himself with all the perspicasity at their command, then they will be believable. Only then can they hope to gain the credibility to delay or avert the crisis. After credibility, it will take courage for an individual to behave as if his personal, perhaps sacrificial, action could make a difference.

I operate from the vortex of my reality - the now, preferring to think of it as parent of the future, rather than as child of the past . . . but I am quite comfortable sitting on the fence. I especially appreciate the value of history in determing the trajectory of an idea. Ledley (1965) observed that within a single decade, the entirely new field of high speed electronic digital computers penetrated almost all phases of modern civilization. At a U.S.A. - Canadian forestry meeting in 1967, Bonnett (1967) presented what today, only 4 years later,

would be considered a very conservative estimate of the promise of the computer for the forester. The recent work of the Blaisdell committee on range research needs (Blaisdell et. al. 1970), while useful, reflects a skillful avoidance of the concepts of computer-usage. My work with the Wildlife Refuge System (Giles, 1968, 1969) outlining computer applications to their massive wildland management problems has made me more conservative (but no less impatient) in estimating the rate of acceptance and application.

Operating in the now, one is forced to discover how to escape the boredom and energy losses of selling the wares of the past that are now available to meet pressing needs, and simultaneously to discover how to predict the future and tool up to meet its onslaught.

I do not use "onslaught" loosely. My analyses all make the long run appear very short. For the forester with a geological world-view, the future seems to have arrived. The various predicted dates for environmental and population catastrophy all virtually coincide. My time frame for the future and the use of computers is best expressed as a distribution. My optimistic estimate for major acceptance and use of computers by environmental management agencies is 5 years. My pessimistic estimate is 20 years; my most-likely estimate is 12 years. Since conditions after 2000 A.D. under present rates will be unbearable, my concern and efforts are for pre-2000. I am not willing to gamble that a host of software systems will become available simultaneously in 1992 or that they will be functional enough to pull a head-strong world into line. I dispair past 1984. I remain functionally attached to the fulfillment of my optimistic estimate. I encourage you to join me in executing affirmative action, in stepping up application, in integrating systems, and in better articulating goals.

Skeptics know I cannot prove the future that I see. I ask them to use a Pascal's wager on the problem; to act as if there is a problem; if there is, they win; if not, they cannot lose much. If yet unwilling to participate, I ask them to get out of the way. If immovable, I ask they reason with me three more

steps. If the rate of change of technology and emergence of social crises and problems is increasing, I suspect they will agree on increases by at least the square. We thus have 9 years to match the preceding 81 years of forestry progress. I doubt if that progress will be a very satisfactory criterion for judging whether we have successfully averted the crisis.

Since many have advocated improved and more efficient educational efforts to solve environmental programs, I am concerned that in the time available, I cannot graduate from a superior program in resource system management more than 12 master degree holders with two years of experience each. There are only two full 4-year Ph.D. program cycles left until my year of concern - 1984.

The third and yet-more-profound problem to face in trying to make the immediacy of the environmental crisis personal for you is that of the slowness of natural processess-growth, recovery and succession. Unprecedented, accelerated rates of growth in man's power over the environment, and constancy or losses in ecological rates is a compounding rate problem. We are already late for our own future.

Before we become more late, allow me to predict for you, frustrated by a passion to be truly imaginative and a desire to be retrospectively "right."

There are two types of "macro-uses" to which computers will be put. I shall emphasize the second, but the first uses are more profound, more subtle, more pervasive, and . . . require more time to treat adequately.

The first are macro-uses. These include the shaping of man, freeing him from physical work burdening him with resolving a new identity as "jobless." The computer has served him, not ruled him, and now though dimly seen, it serves him best when controlled to create the physical, biological, organizational, and technological environment desired.

It will be used to further decrease the relative advantage of experience over knowledge. Capable of updating relations and information, programmed to take the ever-increasing "better" discovery, destined to store more than men now know or have forgotten, the computer will be used to make successive improvements in the useable knowledge of man.

It will be used to meet the realization that, first, men of common prudence cannot understand every political problem that needs to be understood, and second, that such men cannot make laws to deal with these problems. Unless we evolve to a different type of government, it will be the central element in a newly emerging, participatory democracy that supercedes a one-man-one vote with a one-man-one quality-ranked vote. Voting will be conducted after involvement by the voter in a simulation situation. The Delphi Explorations (discussed later) of Umpleby (1970) and others are convincing.

It will be used to shape ideas and philosophies, modify theologies, and expand awareness far beyond unaided limits.

Purpose

In the space surrounding and in between macro- and micro-uses there is everywhere evident the need for purpose--for goals and objectives. The noblisse oblige of the environmental manager requires that he follow the dictate of Norbert Weiner and become more accustomed to formulating human purposes. The statement of purpose is that which man does best; it will not be done by the computer. Only with purpose articulated can the computer be effectively controlled, only then can feedback to man or machine be effected, only then can direction be gained. Without careful development of purpose, there is a tendency to assume that what we have is what we can get and more dangerously, that we can get is what we ought to get. By formalizing "wishful thinking" (and such work can be accelerated and improved) a shadow can be cast seen around the world. That shadow will be of a national environmental management effort, devoid of its present malaise, that has regained the ability to generate its own values. Its action will then be an expression of its purposes, not the manifestation of consequences.

The computer will be used to force precision in statements of purpose. Gross "political paragraphs" will no longer suffice.

Micro-Uses

Often past efforts of predictions have been criticized as exaggerated and even as the root of the anti-scientific movement (Dubos, 1970:xi). Warren Bennis said that "no exaggerations appear true" (Toffler, 1970:23). I strain to exaggerate. Knowing my limits, I see my exaggerations of the future as being historical. I have seen too many of my newest ideas in print only a week later; I have met too many superiors working far in advance of my thought. I dispair at the gap between the content of _Science_, and _Forest Science_ and the _Journal of Wildlife Management_. Thus, I implore the more conservative and skeptical among you to take warning, the future is upon us.

I have a concept of purpose, an environment of opportunity in which man may achieve his highest humanity. This pre-forms my ideas for the future and I struggle to see what is present now but not used, and to foresee what may eventually be used to the point of being judged significant.

Most of us are disenthralling ourselves from the grand eloquence of euphoric computer salesmen of years ago and have gotten down to the hard work of making happen what is possible. Instant solution generators are not available. Computer systems development are not easy, inexpensive, or quickly done. The following is a list of advances that will laboriously come about. These are sorted from my larger matrix on the basis of: _possible_, _preferable_, and _probable_.

Monitors

Computers will monitor waterways first, and eventually terrestrial ecosystems, and will automatically turn off sewage or waste effluent from sources in balance with other users in a water system. The public will control the "keys" to the final physical output control devices, regulated by computer. In some systems, the computer will type out a subpoena or injunction in time to be delivered at the time at which the threshold is projected to be reached.

As hospitals now have complex multivariable automatic analyzers for blood and urine samples, so will environmental management centers have automatic analyzers for ecosystems. The time frame will not be as pressing as for the individual so I anticipate automated subsystems (e.g., a complex punched output from a soil chemistry test, a water test, a deer rumen sample, a soil CO_2 output measurement, and a portable air sampler) will all produce data inputs which along with regional data and a field form completed by a para-ecologist, will be used to generate an integrated report on an ecosystem, its past, present and future potentials and limits.

Hybrid computers will be the center of regional, national, and inter-national monitoring systems. They too will integrate the macro data of satellite surveillance with the micro-data from monitoring stations. They will control sampling rates based on environmental change.

Computers will increasingly be used to produce data for daily or hourly displays of "how things are," like a community fund drive thermometer on the village lawn. New social indicators, complex aggregates of a series of variables, will become the new barometers of change.

The Law

Preliminary decisions on a large number of legal cases will be made by computer. The computer-generated summary will have tested the case for precedents; the consistency of evidence will be checked and inconsistency flagged; and lists made of appropriate retributions. The new role of the judiciary will be to review such outputs, maintain the computer system, and make judgments in the cases of great conflict. Such aid will be essential in the increasing conflicts of the environmental impact legislation. Issuance of permits will approach 100,000 per year. The legal problems associated even with a 1 percent conflict in such cases suggests the need to which man must respond.

Law enforcement in all aspects of environmental management will use the computer. Uses will include analysis of violations, allocation of detection efforts on rational criteria, application of war-time optimal search routines to apprehend revocation of licenses and permits based on multiple law infraction. Our work now supported by the National Rifle Association and the Virginia Tech Center for Environmental Studies confirms this possibility for the near future.

Economic Analyses

The computer will bring together ever-larger land systems for management. The option in WRAP, a computer system I am now developing with TVA, enables the land owner to optimize for the long-term mean and variance of 36 quality-ranked benefit units from his own lands and also to repeat the optimization as often as he desires adding tracts which he thinks he might acquire "if it was worth it." The Wildlife Refuge System has recognized the inefficiencies resulting from individual Refuge managers maximizing, for example, for ducks along the Atlantic flyway, and is exploring means of total systems management.

Large management information systems will be built. Buffington is currently studying the decision making processes of the Wildlife Refuge System to ascertain rationally the information needed to improve decision making. (See Buffington and Giles, 1971.) He provides criteria for deciding what information should go into an input-system.

Another student, C. H. Lobdell, also at Virginia Tech, has taken an alternative approach to building information systems. He acknowledges the need for major volumes of basic data characterizing areas. However, he exploits the Weinbull distribution for gaining probability estimates from experienced wildland managers to generate production functions for game and user-days. The method minimizes data collections which are prohibitively expensive and those that require accounting for such obscure costs as to make the resultant data little better

than estimates. It maximizes the use of the human integrative abilities and experience. The use of such a method in the future will increase because of increasing costs of information and time required for such systems. It will obviously have its limits . . . but the computer can be programmed to announce when these limits are being reached!

The use of large-scale allocation aids will increase. Examples are the Bureau of Outdoor Recreation's COMPARE system for optimizing program of federal and federally-assisted recreation projects, and our current development at Virginia Tech of a related system for the Federal Aid Division of the Bureau of Sport Fisheries and Wildlife. These systems will not take the risks out of environmental decision making, only make them smaller and clearer.

There will be many advances in computer-based or controlled work including statistics, fleet and vehicle optima, inventory systems, optimum regulation of lake water temperatures, land purchase, harvest strategies on fish, and differential uses of parts of a tree (following maximum profit calculations now done for butchering beef).

The list of computer programs of the U.S. Forest Service is impressive. I anticipate a national list in 5 years will be 10 times greater. (But that prediction restores my pessimism; such a list will not reflect adequate skills to solve the environmental problems as I now see them arising).

The Publication and Its Storage

Automated total user data systems like that developed by Buffington (1967) will become a reality. Such systems will automatically deal with, for example, information from the day of hunting license purchase, through multiple mailings of survey questionnaires, through generation of reports complete with mailing labels for users.

Less reliance will be placed on the publication as we know it. The typed printout from a terminal will be discarded after use since the information is still available and is unlikely it will be used again in the same way for the next problem that arises. Current publication results in aggregation, suppression, and eventual loss of micro-information.

Major resource management agencies will develop computer-based library storage and retrieval systems. While continuing to rely upon such literature sources as CRIS, MEDLARS, the Conservation Library in Denver, and the Clearinghouse, individual agencies will build their own systems in response to their specific needs. The slow speed with which inputs are made to national systems will necessitate these developments along with the pressures of diseconomies of size of large systems and special problems of ephemeral literature so prevalent in natural resource disciplines. It is no longer possible or sensible for professional managers of large enterprises to make decisions wholly by intuition and traditional rules of thumb. The future manager needs to base his decisions on accurate, organized knowledge, spending his time considering alternatives rather than gathering and ordering data.

Education

Educational simulators or games like those of Emmett Thompson, Enoch Bell, and my own work with SCRAP, a deer population management game, and WATERLOO, a watershed management game for legislators and regional planners, will increase (see the paper in this symposium by B. B. Bare.) My own work has shown that even non-wildlife students can satisfactorily learn to manage a given deer population in 9 plays of the game. I think such simulators will eventually be employed on television and, in combination with the Delphi Explorations will provide the major hope of assessing mass societal desires and preferences, and guidance in how to educate in order to balance environmental exportations and satisfactions.

I am optimistic that the concepts of Stuart Umpleby (1970) and his group will flourish since they meet the needs of the public resource or land manager who, in my opinion, will be the first arm of government to demonstrate the use of the computer in making functional the rhetoric of participatory democracy. Umpleby advocates the use of teaching computers (like PLATO IV) as a communication system with feedback between planning personnel and the public. The planners could present alternatives with whatever background information that is requested by each

individual. The probable immediate and long term consequence of each alternative, obtained via simulations, could also be a part of the programmed material. Umpleby (1970) says:

> "During the course of the exploration, each individual would indicate his opinion of the desirability of each alternative or could be asked to rank them in order of preference. As he explored the alternatives, background information, and probable consequences, the "explorer" would be able to use a "comment mode" to suggest (a) additional alternatives, (b) inadequacies in the background information provided, or (c) his own judgments about the probable consequences of an alternative action."

These so called citizen sampling simulations seem to me to provide the essential inputs to multiple use decision making. I think you can see the present usefulness of and the projective power of an entry into a computer of an individual's preference statement or goals specific for sex, age, income, and previous experience. If Shafer's concepts of quantifying scenic values are valid, and I think they are, then there is a small gap between combining video tapes of scenes with voter or user preference entries, and thereby reshaping management to be user-satisfying (within certain ecological constraints). The next logical step is to have the user in dialogue with the computer to see how certain decision alternatives do require economic and ecological thresholds to be exceeded. Such use provides the opportunity for modification of decisions based on (1) willingness to take risks, (2) the long-term view, (3) immediate desires, and (4) simple preferences. I am hopeful that effort toward improved computer-based planning; of interactive, real-time citizen participation in goal formulation; and citizen education during the voting process, will be hasty and fruitful. Resource agencies will (or should) make use of the development; perhaps they can encourage and hasten it.

Total computer-guided manpower systems will participate in objective-oriented recruiting, employing, training for the specific needs of the individual and agency, and integrating each individual's expertise and knowledge into computer system up-dates to protect, in an increasingly mobile professional society, an agency's investments in an individual's skills.

In addition to computer-assisted instruction, new learning spaces for university and in-service education will be created. With all factors of the physical environment under teacher control, computers will be used interactively with the class to simulate consequences of management decisions. The computer output will be supplemented by movies, slides, sound, even the odor of ecosystems in a total environment designed to maximize the opportunity of a teacher to efficiently change student behavior. Responses of students will be collected from both physiological sensors and conscious-choice devices, displayed to the teacher on an oscilloscope and digital output, and stored for study of student and teacher performance.

In addition to enabling efficient class-specific educational efforts to be conducted, psychological studies aided by the computer will enable resource agencies to predict aggregate public attitudes as a function of many changing factors such as sex and age ratios. Predicting numbers of types of hunters, and thus the current base of the funding of national wildlife management programs, is essential for continuing viable programs.

A new Extension Service role will emerge in providing computerized management decision services for land owners, cities, and industries.

Simulation and Games

Long-term weather predictions by computer will improve fire control, planting, and land use and management practices. Schemes will be automated for use of such predictions in a game-theoretic mode that provides a written statement of direction like: "Issue for Watershed B a timber contract closure for June 16 through 28 because of the probability that soil moisture conditions in that period, interactive with normal operations, will produce long-term watershed cost inefficiencies."

A massive simulator, based on a core theme of energy budgeting will be available for new regions based on watersheds and air-basings. The simulator will be the new major tool of legislators and legislative aides. It will enable the anticipation of the major long-term consequences of human acts such as clearing forests, building cities, and filling estuaries. It will enable the comparison of the consequences of alternative strategies of taxation, zoning, and payment incentives. Later models will probably focus more on secondary effects, on externalities, than on production.

The present work of ASCUFRO (Dress, 1971) will be recognized as basic to the technology.

Public land acquisition will be dependent upon computer based economic analysis. That analysis will be ecologically based and will reflect some of the work of Mr. Edward Rayburn and Mrs. Susan Rayburn in their studies of Federal Aid acquisition policies and potentials. Acquisition will be decided on, again, energy costs relative to present, sustained, and potential carrying capacity for man as well as wildlife.

Future states of nature will be predicted along with desired future states of nature, and the costs listed that are needed to bridge the gap. It has now been done for wildlife forage areas in the Pacific Northwest (Giles and Snyder 1970).

Research planning and allocation of research funds will increasingly depend on simulation. Funding will be based on analyses of the sensitivity of the system to the various components. The masters thesis by C. W. Smart (1970) at Virginia Tech is an example of such simulation. It provides the basis for optimum design of a research system to deal with the complex problem of epidemiology and control of wildlife rabies.

Improvement in trees, plants and fish will continue with the aid of computer studies of population genetics. However, this will be combined with economic and ecological components in optimization routines that will undoubtedly supress some "good" varieties because of the long term unprofitable consequences (seen through simulation) of planting or encouraging such varieties or strains.

Visual Uses

Rather than generating improved "snoopy" pictures, computers will be used to picture all perspectives of a proposed highway cut, a visitor center, strip-mine, or industry. Even where to plant or to cut trees and the consequences of tree growth on a scene will be graphed. Assessment of visual impact will become a requisite of many development plans. The requirements for drawings will be as routine as requirements for CPM or PERT diagrams for large government contracts.

Computers will be used in pattern recognition. Examples are in data processing of photos from scanning electron microscopes of seed coats of forest and range plants; scans of infra-red adapted photos and video tapes (Driscoll, 1971) for fire, disease, or other stresses; and in automatically calculating rate phenomena in land-use change.

A General Change

There will emerge an apparent solidarity of state and international methods and appraoches in environmental management. There will be the appearance of a universal sameness, not monotony, but a very desirable loss in the dramatically different approaches which have characterized, for example, state game and fish agencies. The wide range in performance was tolerable when the computer was a large accounting machine, but now that it is capable of significantly aiding upper management, the situation is no longer acceptable. Resource care or abuse is now at stake, and the differences are obvious.

The computerized methods employed will be dynamic but more homogenous due to the increasing role of an efficiency of feedback and automatic systems control concepts.

Strategies

By the act of prediction, the system being predicted is modified. I hope I have modified the environmental management system. Predictions will not be enough to accomplish the changes needed to significantly increase computer usage. There are other strategies for doing so.

The Student Strategy - We will need to hold out to the student a program and the motivation to resist the siren call of tree and furry animal and to participate in the struggle of shaping the environment with the most powerful tool on the scene. We will need to get some of them to do something now, for man, through resources, while there is yet time. I despair at chances for major university change. My hope is that a few great system managers will emerge; only a few are needed. With a computer, one man can move mountains. In addition to moving "mountains," he will quicken the pace of the agency, aid in formulating objectives, and create sub-systems of various sorts and sizes to enable improved agency participation in the universal management act.

The Research Strategy - For many of the previous predictions to come true, sequential research as well as software development will be proportionately lower than simultaneous efforts. The efficiencies in the sequential strategy were good justification in the past. Now there is a no-time situation and effectiveness, not efficiency, will be the criterion for selecting a research and development strategy. We will "go simultaneous."

The Design Competition Strategy - There will be increasing stress on "design competition" as in architectural circles. The competition, on the surface appearing to be duplication of efforts, will avoid the erosion of local and individual specialities or theories caused by a centralized national or international idiom.

The Machiavellian Question - Since it seems futile merely to state the needs for computer applications to solve environmental problems, and since governments so rarely mobilize to meet expected disturbances and problems, then it seems that the ethical question must be faced: Given predicitive knowledge (augmented by computers), is it ethical to "mold" the public, even to mislead it, so that present legislators will so act now that resources and capabilities will exist in the future for solving problems then? If the mass public does not see the need and governments do not mobilize, then I see only one unfortunate end.

The Seminar Strategy - Management seminars at adult learning centers and Extension facilities will be essential to enable executive decision makers to see the uses of and encourage the application of computers in (at least) environmental dimensions of their decisions. Computer games such as WATERLOO to be used at executive institutes will be one medium.

Recycled and New Data - For the next 3 to 5 years, the major advances will be made in recycling existing data. These efforts will separate the need-to-know from the nice-to-know data, provide input to optimal research and data-collection system design, and, I am afraid, converge with on-going data collection efforts with explosive results! There will be much apparent "waste". What information "might be useful one of these days" will become increasingly irrelevant under the pressures of the late '70's. There will be a public and scientific storm that will retard efforts to convince the public to support computer-aided cures to their environmental sickness.

Closure of Information Systems - Information systems dependent upon characterizing social, economic, sex, age, race, and psychological characteristics for predicting user satisfactions, pleasures, and user types will be closed out. Over-restrictive federal legislation on computer information systems will result from abuses of computer data banks, recurring McCarthyism, and events like recent CIA - law enforcement agency file controversies. It seems necessary to recycle much data and catch-up on much sociological and economic work before the information bank controversy closes the doors. I suspect use of a paid questionnaire "jury" will become popular just as will use of non-parametric treatment of values, desires, and satisfactions. Subjective probabilities will be used with such aids as the Weinbull distribution.

Triad - It is a difficult time to grow up, let alone grow strong. A general three-dimensional set of tactics will be required: to so stimulate interest that inaction is broken; to counter negative attitudes; and to engage rapidly and as conspicuously as possible in positive action to increase computer usage on environmental problems.

Conclusion

There are enough problems to meet and changes to come to make life pretty exciting. That one very powerful tool for meeting these problems _is_ available makes it very attractive. There is danger that when one has a good hammer he treats all problems as nails. But we're past that . . . almost. However, the computer is not _simply_ another tool. Do not make that mistake. It is a shaper of thought pattern, a forcer of ideas, a demander of precision, a user of logic, a tester of theories, and a predictor of the future. If it were simply a new tool it would only add one more line in a decision-tree representing alternative strategies. The computer changes the entire decision tree and adds _n_ overlays. The whole essence of environmental management is changed. Man _can_ have control . . . if he grasps the glad committment. He must commit a sufficient input of power to achieve the "escape velocity" to free the computer-based efforts from the gravity of 80 years of governmentally-conditioned environmental "tending." Guidance of the new effort will be needed and difficult. Instability will be recognized as a necessary but undesirable attendant to the desirable flexibility.

I exist on the pessimism-optimism continuum, a proper place. I am pessimistic about the face of the future and about the success of efforts to change it. My pessimism feeds my optimism that something can be done. It is a difficult and grand experiment. The source of creativity is the tension between the known and the possible, the now and the future. I am not so naive as to believe we will generate instant New-man. Bearded or not, man will tend to be as hard-headed, hard-hearted, egocentric and perverse as men have always been. But there is a situation coming, already creating a New-man. He will not have as clear a view of history as past civilizations because there is more of it and the "relevant portions," those in recent times, will be most studied. In addition, because of the same rate problem affecting the immediate past, he will not have as clear a view of the future. It will appear indecipherable. Thus, the question of goals and purpose will loom larger than ever. The future is here today; we are born into it. Our constraints are historical, our goals future.

Both seem non-existent. We have come to the divide. We can now, we must, decide who we are. We can in all but the shortest run decide the kind and scale of resources and environment we shall have. We can protect ourselves from environmental deterioration with our technological ombudsman, the computer. We can create a fit environment - abundant, clean, diverse, secure and full of opportunity - a place where man can discover his highest humanity.

Literature Cited

1. Blaisdell, J. P., V. L. Duvall, R. W. Harris, R. D. Lloyd, and E. H. Reid. 1970. Range research to meet new challenges and goals. J. Range Mgmt. 23(4): 227-234.

2. Bonnett, H. W. 1967. The computer: its promises and limitations. A paper before the joint Canadian Institute of Forestry and Society of Amer. Foresters, Ottawa, Canada. Unpub. M.S. (Mimeo) 10 pp.

3. Buffington, C. D. 1967. A computerized system of harvest analysis for Idaho big game management. M. S. Thesis, Univ. Idaho, Moscow. 213 pp.

4. Buffington, C. D. and R. H. Giles, Jr. 1971. Methods for obtaining and evaluating inputs for management information systems for wildlife agencies; Proc. Southeastern Assoc. of State Fish and Game Commissioners, 25: (in press).

5. Dress, P. E. 1971. Proceedings of the symposium on environmental quality research in forest resources. A report of the Assoc. of State College and University Forestry Research Organizations, (working copy) September, VII + 32 pp.

6. Driscoll, R. S. 1971. Color aerial photograph -- a new view for range management. USDA Forest Serv. Res. Paper RM-67, 11 p. illus. Rocky Mt. For. and Range Expt. Station, Ft. Collins, Colorado 80521.

7. Dubos, R. 1970. Reason awake: Science for man. Columbia Univ. Press, New York, N.Y. XVIII + 280 pp.

8. Giles, R. H., Jr. 1968. Operation CONVERGE: An analysis and plan of action for the National Wildlife Refuge System, July. Unpub. Manuscript, 301 pp.

9. Giles, R. H., Jr. 1969. Systems for the refuge system: a refuge manager's handbook. Division of Wildlife Refuges, U.S.D.I., multilithed consulting report, 110 pp.

10. Giles, R. H., Jr., and N. Snyder. 1970. Simulation techniques in wildlife habitat management, p. 23-49 in Jameson, D. A. (Ed.) 1970. Modeling and systems analysis in range science. Range Sci., Dept., Sci. Series No. 5, Colorado State Univ. Ft. Collins, 134 pp.

11. Ledley, R. S. 1965. Scope of computer applications p. 250-291 in H. J. Morowitz and T. H. Waterman. Theoretical and mathematical biology. Blaisdell Pub. Co., New York xvii + 426 pp.

12. Shafter, E. L. J., and S. Mietz. 1970. It seems possible to quantify scenic beauty in photographs. U. S. Forest Service Research Paper NE-162, Northeastern Forest Expt. Sta., Upper Darby, P. 12 pp.

13. Smart, C. W. 1970. A computer model of wildlife rabies epizootics and an analysis of incidence patterns. Unpub. M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Va., IX + 126 pp.

14. Toffler, A. 1970. Future shock. Random House, New York, N.Y. XII + 505 pp.

15. Umpleby, S. 1970. Citizen sampling simulations: a method for involving the public in social planning. Computer-based Education Research Laboratory Report X-12, University of Illinois, Urbana, iii + 28 pp.

COMPUTER SYSTEMS, ACCESS, AND ADMINISTRATION

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Hardware

The initial component that must be considered in describing a computer system is the hardware -- its capability, versatility, speed, reliability, and convenience. I am not going to bore you with a host of specifications, but since I propose to limit my discussion to large computing systems -- the only efficient kind -- it might be well at the outset to name manufacturers and models that at least merit consideration.

Biggest and best known manufacturer is IBM. Of their older models, only the 360/65 or larger machines should be considered. They rent for about $50,000 per month, have add times of 1300 nanoseconds and memory cycle times of 750 nanoseconds. The newer 370/155 rents for about the same, but has add times of 115 nanoseconds and cycle times of 345 nanoseconds. Better machines are the 370/165 and the 360/195; add time and cycle times are only 80 nanoseconds for the first and 54 nanoseconds for the second, but monthly rentals are about $90,000 and $200,000 respectively. To put times in perspective, a nanosecond is one billionth of a second -- light travels slightly less than one foot in that time interval.

The only Univac equipment worth considering is the 1106-1108-1110 group. Add and cycle times for each are 1500 nanoseconds, 750 nanoseconds, and 300 nanoseconds. Monthly rents range from $40,000 to $100,000. A Univac array processor with 250 nanosecond add speed facilitates array manipulation at 20 times the above speeds.

In the past, Honeywell has manufactured only small or medium computers. However, they recently merged with GE, whose GE 655 rented for $80,00 per month with a 1900 nanosecond add time and 500 nanosecond cycle time. Honeywell recently came out with their own 6000 series, renting for from $25,000 to $75,000 per month. Add times presumably are somewhat less than the GE, and cycle times are about the same.

Burroughs pioneered many worthwhile concepts with their old B5500 (virtual memory, use of ALGOL for system programming), but it is now obsolete. Their B6500 has 400 nanosecond add time, 500 nanosecond cycle time, and rents for $75,000 per month. The B6500 coupled with their Illiac IV array subsystem has a revolutionary amount of parallelism (64 CPUs) which make effective add time only 10 nanoseconds if 64 elements of an array are being processed. Similarly, effective memory cycle time is only 7 nanoseconds. Rental is estimated at $600,000 per month.

CDC's 6400-6500-6600 and 7600 have add and cycle times ranging from 1100 nanoseconds down to 27 nanoseconds, with monthly rentals ranging from $50,000 up to $200,000. In addition their new STAR-100 (a string array processor with pipelining and parallelism) is expected to rent for $400,000 per month and have effective add time of 10 nanoseconds and effective cycle time of 80 nanoseconds.

Until two weeks ago, a 6th marginal manufacturer would have had to be mentioned. RCA parallelled the smaller IBM 360's with a Spectra series. Even their largest model in this series--the Spectra 70/55 -- was really too slow -- it had 2580 nanosecond add time and 1000 nanosecond cycle time, and rented for about $25,000 per month. The newer RCA 6 and 7's were to have been delivered this month -- they were in about the same rental bracket and had 765 nanosecond cycle times.

The 5 manufacturers just named account for the only large delivered 3rd generation computer systems still in production in the U.S. Soon Xerox is supposed to deliver a Sigma 9 with 730 nanosecond add time and 900 nanosecond cycle time, and NCR

is supposed to deliver a Centruy 300 with 1300 nanosecond add time and 650 nanosecond cycle time. These are the first attempts by these manufacturers to compete in the large computer market. Monthly rentals of $50,000 and $30,000 respectively have been quoted. No foreign manufacturers have been able to crack the large computer market in the U.S., although England's ICL 1906A might technically qualify. Germans, Japanese and others make only small or medium computers and components.

Firmware

Naked hardware of the sort just described is valueless unless it is coupled with firmware and software that enable the user to input his data, execute his programs, and output the results. Firmware can be thought of as miniaturized, easily interchanged circuitry or magnetic bit configurations. The circuitry may be monolithic integrated circuits, while the bit configurations are usually thin film read-only memory involving micro-programs. In either case, the firmware replaces hardwired instructions or logic circuits composed of logic gates, adders, half-adders, shifts, etc. When micro-programs are involved, they either invoke parallelism or specify a series of micro-instructions that do not require a full machine cycle for each operation. Microprogramming allows emulation of one computer on another, or equipping any computer with an instruction set resembling that of some higher language such as Fortran, Algol, Cobol, etc. Microprograms have obtained 10-fold speedups over standard assembly language programs on such sophisticated machines as the IBM 360.

Software

Software, as opposed to firmware, consists of control programs and application programs -- in the form of magnetic bit configurations that are input to the computer in a normal manner (as data) rather than as sheets of circuitry or thin-film read-only memory. Software allows users to exploit hardware and firmware without becoming bogged down in a morass of circuitry, microcircuitry, or thin film microprograms. All

efficient computers are now controlled by an overall monitor system requiring little operator intervention. These monitors call in subsystems as needed to process users' programs. Names of various monitors are OS 360 and DOS 360 (IBM), GECOS (Honeywell and GE), EXEC VIII (Univac), SCOPE (CDC), and MCP (Burroughs).

Monitors require special signals in the stream of input from users. These special signals were once called control cards, but are now more commonly called Job Control Language (JCL), since they may be input from teletypes. JCL differs radically among manufacturers, and even among different generations of equipment of the same manufacturer. Some JCL is logical and involves default options that most users can live with. Other JCL is wordy, irrational, and unforgiving if full detail is not supplied for most options. An increasing amount of JCL employs Fortran-like terminology.

Users need to learn a minimum amount of JCL to benefit from any computing system. Any user who remains completely dependent on a programmer to prepare simple input to a computer will soon be replaced by a more versatile individual who can converse on a modest level with the computer.

Below the level of monitors and other control software is applications software. This varies all the way from subsystems such as SIMSCRIPT, GPSS, LP, PERT/COST, CPM, COGO, APT, APL interpreters, FORTRAN compilers, and text editors to smaller programs that manipulate matrices, fit regressions, or handle accounting. Users owe it to themselves and to their employers to learn what alternative computer systems have available in the way of subsystems, and to get a rough idea of the content of various application program libraries available on each. However, the user who is a member of a resource management agency cannot rely on finding what he needs in program libraries -- he should be able to write an adequate program in higher language that will accomplish nearly any straightforward job.

Programming Language

At this point, it would be well to stress the idea that any programs of lasting value should not be written in machine code or assembly language. The onerous reprogramming job involved each time a hardware boundary is crossed or a new computer generation arrives can only be avoided if higher language is used initially, with special care to build in maximum compatibility. The only higher languages now reasonably standardized by ANSI (old USASI) are FORTRAN and COBOL. ALGOL's lack of continuity rules it out of consideration as a stable higher language -- ALGOL 68 left in its wake a host of programs unhappily written in ALGOL 60 or ALGOL 58. Hopefully, PL/I or APL may someday become stable enough to warrant consideration, but at present they seem to be still evolving.

Even with FORTRAN or COBOL, the user must be careful to avoid known incompatibilities and to avoid exploiting non-standard but locally available goodies. Word length no longer than 32 bits should be assumed for alphameric data, and the user should try to facilitate conversion to double-precision arithmetic should imprecision of later hardware require it. If Fortran is extended (not revised) to facilitate string and bit manipulation and to allow list-oriented and data oriented I/O as well as formatted I/O, it will be the first broadly applicable language to demonstrate the stability needed by computer users. It is most unfortunate that COBOL was conceived as a competitor to FORTRAN instead of as an extension, since it is very inefficient in arithmetic indexing of arrays. So much for the broad view of computer systems -- hardware, firmware, software.

Access

Let us now see how users gain access to a large computing system. A major factor affecting access is WHO controls the computing system. Most users belonging to organizations that have arranged for exclusive use of a large computer (through lease or purchase) are allowed little freedom to use outside computer systems. They have the opportunity, however, if they are high enough on the hierarchical totem pole, to exert influence on internal computer policies and decisions. When poor internal decisions are made, members of the organization who use the computer are usually penalized without any recourse.

Two major mistakes are frequently made in initial procurement of large computing systems: first, selection of an inferior system because of improperly taking into account needs, cost/performance, and advantages of buying time on someone else's large computer; second, purchasing instead of leasing the system; such a mistake is easy to make if one listens uncritically to accountants who are ignorant of the costs of obsolescence and overly enthusiastic about the benefits of long-term depreciation.

Organizations are generally less alert to obsolescence when they own equipment than when they lease it. Top echelons often are willing to doom their users to continued use of an obsolete but fully-owned machine because the hidden costs of obsolescence are never explicitly brought to their attention. Finally, repairs and maintenance of fully owned systems are usually inferior to what can be obtained for a system leased from a manufacturer with appropriate penalties for down-time.

Most resource management agencies (public or private) either control no computer or have only a small or medium-sized one, neither of which can provide them with large system capabilities or efficiencies. When they make it difficult for their employees to access effective outside computers, they are being shortsighted and wasting stockholders' or taxpayers' funds.

Even when they allow voice-grade teletype access to large outside computers, they are not taking care of the really worthwhile jobs that involve massive I/O. Until switched broadband data transmission is available (this will be discussed below), resource managers must rely on physical card or tape transport of large masses of data to outside large computers. Most resource management agencies should acquire small or medium sized computers not for stand-alone processing of data, but for card-to-tape condensing of data to be processed elsewhere, and for tape-to-print output of such outside processing. Where such suitable I/O computers are acquired, massive inputs from cards, cassettes, or OCR can be appropriately formatted and written on batch input tapes for processing by a variety of large outside computers. Computer outputs can be spooled onto tape or disk and transported back to the agency for printing.

The alternative to physical transport of tapes or disk is broadband, burst mode transmission. At present AT and T offers such service only on dedicated (24 hours per day) rather than switched (metered for time actually in use) basis. Costs are exorbitant considering the fact that the dedicated lines would be unused 99% of the time. In addition to $825 per month for 2 service terminals (including modems), Telpak A (16 voice grade lines) costs $30 per month per mile, and can transmit only about 40,000 bits per second (about 4,000 characters per second -- at least 10 times this speed would be desirable to approach tape-to-tape speeds).

Hopefully, a recent FCC decision in favor of Datran (UCC) and MCI will ensure competitive switched broadband services in two or three years. Inability of computer utilities to offer switched broadband burst-mode services at present prevents many potential users from exploiting remote batch processing on large outside computers.

Input Options

Batch input (where cards or tape are input on site and are queued by priorities for straight processing, multi-pramming, or multiprocessing) is the bread and butter of everyday computing, and wastes the least computer time in overhead and the least programmer time in error correction.

Remote batch input (where cards or tape arrive on site over a telephone line or broadband connection and are therefore treated just like batch input) involves some overhead to handle telecommunication, but is otherwise processed as efficiently as batch input.

Demand input (where users on a teletype or other terminal converse interactively with the computer) involves extensive overhead, since the computer uses only a very small time-slice to react to each input, but cannot do much until all transmission from the user has been received. Voice-grade telephone lines can transmit only about 300 characters per second.

Real-time input (where an interrupt truncates all jobs being processed until the real-time input has been processed) is essentially very wasteful, but it is primarily only used for high-priority activities such as process control, guidance of satellites, receipt of telemetry, etc.

These 4 broad types of input -- batch, remote batch, demand, and real-time -- characterize all access to the computer, regardless of who controls it.

Because voice-grade teletype terminals do provide demand access to large computers, "time-sharing" and "interactive" computing have been touted as the solution to most computing problems. Such hookups are suitable for accessing information systems where queries or update do not involve massive I/O. They are useful in education, where students can get instant responses to reinforce their learning process. They are useful in developing small or trivial programs, in executing large library programs that only need small amounts of input data, and in operating in the desk calculator mode.

Other than in the above situations, batch or remote batch access is to be preferred for the sake of efficiency. In the case of nontrivial program development, interactive programming wastes a lot of programmer time waiting for compile and for one-by-one error detection.

Computer system input and output can be in several forms -- punched cards, magnetic tape, printed sheets, magnetic ink, cathode tube displays and light-pencil input from cathode tubes, to mention a few.

Temporary storage for input, output, or intermediate results can be in high-speed addressable memory (thin film, plated wire, core), addressable bulk storage (drum or disk), or on magnetic tapes.

One new development is expected to have tremendous impact on both I/O and memory -- the use of a laser to either permanently or temporarily record bits on thin film

at fantastic densities -- as high as 6 million bits per square inch. If user output can be spooled individually to such small bits of film, the user can examine it page by page in cathode tube display at leisure, making hard Xerox copy only of the few permanently useful pages. This will greatly reduce the current waste of paper on printout that is briefly scanned and discarded.

Administration

The last topic to be discussed is the administration of computing systems. One aspect has been briefly alluded to already -- the urge of inefficient administrators to forcibly channel all agency computing to the inhouse facilities, however inferior. Such fiats may result in computing costs 10 to 30 times as high as they would be if efficiently processed elsewhere. A rigid "inhouse" computing policy is usually a defense mechanism to prevent unfavorable comparisons that might trigger internal reorganization.

A well-run large system controlled by an agency is usually so convenient and efficient that it has nothing to fear from cost/performance comparisons with more distant nonagency systems. When certain special types of job can more efficiently be done elsewhere, the agency as a whole benefits from such a wise use of resources. When only small computers are available inhouse, the agency benefits from having all computing done elsewhere and using its small computer merely for I/O preparation.

Enlightened users have a real interest in making price-performance comparisons between their own agency computer and convenient outside computers, and should not be hampered by empire-builders. Such comparisons require a well designed mix of benchmark programs written in higher language (preferably Fortran) acceptable to all lange computers.

Features such as capability of handling sort/merge, overlays, program library maintenance, file updates, and the availability of desired subsystems must be taken into account as well as compiler adequacy and direct dollar cost of processing. Degradation of system performance under various loads should also be taken into account if detectible.

Price-performance of a large computer system should constantly be studied by the administrators themselves with a view to improvement. If it seems desirable to channel some use to more efficient outside systems, inconvenience to users and more effort required of them should be weighed before the decision is made.

Equitable administration of computing systems must establish several priority levels -- at a minimum priorities will vary among batch, demand, and real time jobs. Additionally, it will usually be desirable to subdivide the batch-remote-batch queue into at least 3 priority levels (A,B,C). These may be user-assigned (coupled with charge differentials) or they may be based on core-requirements and run-time estimates.

Complicated priority or pricing algorithms are undesirable both from users' and administrators' points of view. However, charges should be graduated so that user-specified high-priority pays more for CPU time than does user-specified low-priority. Steep differences in rates may be necessary to avoid overuse of highest priority.

Where a large-scale inhouse computing system is available, funds to support the entire center are often allocated at the beginning of the year, then time is "given" to various organizational users in accordance with their estimated or budgeted needs. Such a policy tends to downgrade responsiveness to users' suggestions and requests, especially when research in computer science has been blanketed into the administration.

Computer research should be funded separately, just as other departments in the organization. A more user-oriented administration is usually ensured if direct allocation of funds is sufficient only to cover the expense of the center director and a small top level staff; other expenses should be met out of a working capital fund that must be replenished out of receipts earned from use.

Charge schedules can be varied by priority to minimize peak loads, and should be adjusted to ensure maintenance of the working capital fund. At the end of the fiscal year, profit can either be prorated back to users as credits for the year ahead, or otherwise used as agency top management decides.

Large university computing systems differ from resource management agencies in that educational objectives usually constitute their dominant mission. Faculty research, business administration, and service to the nonuniversity users are secondary objectives. Consequently, the educational mission should be initially funded, along with the director and top staff, but the working capital fund should be used to cover expenses to be recovered from all non-educational use, grants, etc.

Funds for computer use should be initially allocated to departments, but would not automatically be paid to the computing center until services had been rendered. The above arrangement gives users a real vote in how the computer center is to be administered. Private computing utilities, of course, are run for profit, so they must be responsive to user needs and preferences or they will go broke.

No completely successful large-computer utility has emerged, although a number have been quite successful servicing demand-mode customers (time-sharing). The broadband obstacle to mass data transfer has prevented much remote batch service, so the bulk of massive I/O is either carried by hand if the utility is close by, or done locally on small, inefficient computers.

The existing computer utilities are finding security of information is a major problem when a heterogeneous group of users has any kind of remote access (demand or batch). A new type of criminal is taxing the ingenuity of both hardware and software designers; however, really important information can be encoded so that there will be little if any profit in theft.

One last point about administration of a computer system deserves mention. Just as it has been found short-sighted and costly to skimp on preventive maintenance of hardware, so is it stupid to skimp on maintenance and expansion of system software. A minimum of 4 or 5 really expert system programmers should be budgeted to system software upkeep.

Users will gladly pay extra charges to support a staff that kills system bugs as they are detected. Logic flaws in system software cannot be tolerated for long, and the appearance of stray bits or the disappearance of genuine bits in the frequent copying operations must be remedied when sensed, although, this may admittedly be a tricky job. System-supported application program libraries must be constantly culled, updated, or expanded. System I/O bugs continue to crop up in supposedly bug-free systems, and no ordinary user should be expected to diagnose or cure them. Although hardware and software manufacturers bear much responsibility for system software -- and manufacturers who shirk this duty tend to lose future sales -- computer center administrations cannot shrug off their own responsibility to act when manufacturers are remiss and the users get shot down in droves by a faulty system.

Conclusion

The views expressed above are my own and do not necessarily represent the official position of the U. S. Forest Service. Possibly there are people in this room who do not agree with me completely. However, I speak from experience as an enlightened user who has run on someone else's computer since 1957 -- service bureaus', Federal agencies', universities', or industry-owned. The equipment has ranged from IBM 704, 7040, 7040/7094 DCS, 360/40, 360/50, 360/67; CDC 6400; Univac 1108; B5500; GE635.

Though occasionally forced to program in assembly language, the bulk of my programs written since 1962 are now in a broadly compatible subset of ANSI Fortran acceptable to all large computers. This has required special care where overlays, sorts, and character-sensitive or word-length-sensitive features were involved.

Only those who have achieved similar compatibility and have been able to run identical programs on a number of large computers have a firm basis for preferring one large computer to another. However, there can be no serious argument that the cost-performance of almost any specific large system is better than that of almost any small or medium-sized system over the complete range of jobs we should be doing on computers.

COMMENTS ON LEWIS R. GROSENBAUGH'S PAPER, COMPUTER SYSTEMS ACCESS AND ADMINISTRATION

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I would like to preface my remarks with a quote by one of the giants in the field of computation, Dr. R.A. Hamming; "The purpose of computing is insight not numbers". I think Lew would be in full accord with Hamming. Lew has done an excellent job of building a case for the large computer. In terms of economic efficiency, the only efficient computers are large computers. Only with the large computer can we economically do the calculations that provide us with insight not numbers.

As is so often the case, when you buy a dog you are likely to get some fleas also. So it is with large computers. The operating system, at least for the IBM 360 series, demands a great deal in terms of overhead. The requirements of an operating system such as OS/360 in terms of core memory, auxillary memory and CPU time can become significant. The OS system at times reminds me of myself. It is so busy deciding what it should do next, whose I/O should be handled, who gets this block of core, etc., that it can't <u>do</u> anything. Of course, in a more serious vein, the OS operating system is a very flexible and general system and you must be prepared to pay the price for such flexibility and generality.

I agree with Lew that most programmers should write in a higher level language. I do believe that PL/1 is stable enough to warrant consideration. Of course, with PL/1 you are presently a captive of IBM, but other vendors are making rumblings about PL/1 compilers. With a language as powerful as PL/1, I really see no need for application programmers to resort to assembly language. I am especially impressed with the APL language. If you like the language of mathematics you will probably feel at home in APL. If you are "turned on" by exotic operators and symbols, then APL should be your thing.

With today's hardware, I am not quite as afraid of technological obsolesence as Lew, especially with the central processor. I will agree, that in the past, many risks were associated with machine purchase, but I firmly believe that these risks have decreased considerably over the past 4 or 5 years. I still feel that the purchase of peripheral devices, especially disc drives, data cells, tape transports and maybe printers is questionable. It is generally felt that a 5 year service life will be fairly close to the break-even point between owning and leasing.

I do feel strongly that, especially in the past, many organizations have been too hasty to swap out computer systems. The average user of a computer system quite often barely learns how to efficiently and effectively use a system before it is replaced. I firmly believe that a period of 3 to 5 years is required to the average user to really know how to use a system. This is based on the following premises.

1. Historically, the operating system supplied by the vendor for a new computer is usually very "dynamic" or unstable for at least the first two years. As I recall, our School went through 16 releases of OS during approximately a 24 month period. Changes of this frequency and magnitude posed tremendous problems for systems programmers, operators and applications programmers. Programs that used to run would abort. Untold amounts of time, both in terms of personnel and machine, were spent in program and/or Control Card modification as a result of new releases.

2. Once the operating system is relatively stable and new releases are "transparent" to the user, a period of time must elapse before the user is "comfortable" with the system and really comprehends how to make efficient use of it.

I agree with Lew that giving every forester a teletype terminal is not going to solve the access problem. However, I am sold on the utility of conversational or interactive terminals for training of students for certain types of information retrieval applications for replacement for a desk

calculator and for debugging large application programs. By utilizing the REMOTE JOB ENTRY capability of most terminal systems, the programmer can easily modify or correct errors and resubmit the job batch processing from his terminal. Therefore, the reading of large card decks by a card reader can by bypassed. This procedure of course demands that the computer center have available large scale intermediate storage devises such as discs or data cells to store the programs.

I strongly urge you to pay heed to Lew when he tells you that you can't rely on a program library or libraries to handle all your data processing needs. A number of the staff of a resource agency should be able to accomplish the writing of a relatively straight forward program in a higher level language. Until the worker can do this, I feel he will not be able to bring the power of the computer to bear on his area of specialty and will probably commit several "Type III" errors. He will modify the problem to fit an existing program that is in some applications package. In other words, he will get an answer to the wrong problem.

It is very difficult, even in high level languages, to write code that is compatible to several machines. IBM is to be commended for their effort in writing manuals that clearly point out ANS standard. For example, the release 20 FORTRAN manual clearly indicates IBM extensions by having the non-standard features shaded. Thus, if one wishes to write code that is relatively compatible across machines, he can easily determine which features are standard FORTRAN.

Having spent most of my productive life inside a computer center and the last four years outside, I realize that one's viewpoint changes drastically when a person switches from inside to outside. As a user, I agree with Lew in his observations concerning the administration of a University computer center. As a former computer center administrator, I know how tough it is to satisfy a large group of users. As Lew points out, the only way the user is going to effectively have a voice in the administration of a center is to control

some of the purse strings. But a computer center director can't work for a committee. It has been my experience that a computer center director has to be a bit of a dictator. Nice guys really finish last as computer center directors. If you try to make conditions optimal for all users you get ulcers, hypertension, a bald head and lots of enemies. It seems to me the director of a computer center must be a "satisficer" not an optimizer......you don't make anybody completely happy, but maybe you can get a system that a majority of the users can live with.

In conclusion, I think we can all profit from Lew's experience. Lew hasn't suffered from the "Paul Principle". The "Paul Principle" states that most computer center directors have been bypassed by technology and as a result still think in terms of 1st and 2nd generation data processing methods.

If we don't learn anything else, let's recall that if you get 15 small computers, you can still solve only small problems, even though you can solve 15 small problems simultaneously. You still can't tackle the real meaningful problems that cry for solution. The key to access is communications. Let's all hope that in the immediate future switched, broad band data transmission will become a reality. When this transpires, then the access problem will almost be solved.

QUANTITATIVE ANALYSIS IN A QUALITATIVE WORLD: MODELING FORESTRY SYSTEMS TO IMPROVE DECISION MAKING

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The world today, in spite of the vast progress made in mathematics, computer science, statistics, operations research, management science, and the rest of the many quantitatively oriented sciences, remains largely and amazingly qualitative. By and large, interrelationships, particularly those involving human beings, have resisted measurement in a quantitative sense. In fact, in recent years there has been a trend towards the less quantitative aspects of life, even as the quantitative sciences have continued to flourish. This is true in general and is no less true in forestry.

It appears desirable at this point to explore the boundary between quantitative and qualitative measurement. Measurement theorists have generally termed as "quantitative" that measurement made in the ratio scale, whereas qualitative measurement is made in the less powerful scales, e.g., nominal, ordinal, and interval (Note: Various theorists may differentiate either additional or fewer scales). To nonscientists, however, anything susceptible to measurement normally is termed "quantitative".

We should recognize that natural resource data is a very diverse mix, measurement-wise. Consider, for example, the traditional general categories: (a) timber resource data, (b) range resource data, (c) water resource data, (d) fisheries and wildlife resource data, and (3) recreation resource data.

Within the category of timber resource data we may include such items as tree species classification, tree size distributions, tree volume, area of commercial forest, and timber grade. Similar items are found in range resource data.

In water resources we find such items as type and amounts of pollutants, flow rates, turbidity, oxygen levels, and sediment levels.

Within the category of fisheries and wildlife resource data, we may include such items as species distribution, body size, migration routes, diet, and predators.

In recreation resources we find such items as plant and animal species classification, geologic formations, climate, distributions of facilities.

Note that in each major category of resource data, it is possible that variables will be measured in scales ranging all the way from nominal to ratio.

Items thus far have been concerned largely with the biological or physical features of natural resources. When we look to the human side of natural resources, things become even less quantitative in the measurement sense of the word. The human side is concerned predominantly with owners and users of natural resources. Here we may be concerned with such items as: (1) age of the user or owner, (2) occupation of the user or owner, (3) ethnic and national origin of the user or owner, (4) type of business (corporate, partnership, etc.), (5) location of the business relative to suppliers and customers, (6) race of the user or owners, and (7) attitudes of operators regarding resource conservation, use and development.

There are some definite measurement problems associated with these types of data. These data items range from very impersonal to very personal characteristics of owners and users. This means that we may expect a variable degree of resistance from the respondent when he is surveyed.

In the cases of both types of data--physical resource and user characteristics--there are instruments to be employed. In the case of the physical resource data, when we speak of "instrument" we are using the term in the way that most laymen understand the term. That is, we are referring to an object that measures some other object to a certain level of precision. In the case of user characteristics, the use of the term "instrument" is generally one unfamiliar to laymen (i.e., a survey questionaire).

Although the two types of instruments differ considerably, nevertheless there are certain common concerns. For instance, both types of instruments have a characteristic and inherent precision level. It is true, however, that this level is very difficult to ascertain in the case of survey instruments. Another common characteristic is that both measure in units that are essentially arbitrary regardless of the scale of measurement involved. Thirdly, both types of instruments are devised by man, and hence are continually subject to change and improvement.

Another characteristic possessed by both types of instruments is the possibility of bias, although not in equal degree. The survey instruments are most susceptible to the introduction of bias.

The above brief comments are included to lay a foundation upon which we may base a discussion of quantification problems in natural resources. Data by themselves are not particularly useful and very likely their collection could not be justified if mere summarization and display were the end products. Data are important because human beings are constantly confronted with decisions that must be made and data are required if decisions are to be made in a responsible manner. This is true in forestry as well as in every other human activity.

I will discuss now the role of data in decision making and then proceed to a discussion of resource decision making and how computing systems may assist in this activity.

Given that natural resource data ultimately are most useful to decision making, it is necessary that such data elements be organized in a data system or data bank so that they might be retrieved and processed systematically into information inputs useful to decision makers.[1]

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1. Data consists of raw, unprocessed perceptions or measurements or observed behavior of the variables under study (Holm, 1968, p. 112).

Inter-relationships between the decision system, information system, and data system are shown in Figure 1. By a data system, I mean a system designed to locate, store, select, and process data elements according to some set of decision rules (after Holm, p. 112). We can think of the decision system as consisting of a group of inter-related decisions and each decision represented by one or more decision rules. A decision rule is simply a formulation (often in the form of a mathematical equation) that indicates what variables influence how a decision is made and how these variables are related to one another.

In order to solve each decision rule, some information will be required. It is the role of the information system to provide these inputs. By "solving each decision rule," we mean "making a decision." The fact that a decision must be made and sufficient information is not available on which to base the decision may be considered an important management problem.

The information system must depend on the data system to provide its inputs. Information is formed by processing, analyzing, evaluating, reducing, and interpreting raw data in the data system. (Holm, 1968, p. 112).

In looking at the flowchart (Figure 1), keep in mind that several of each type of system (i.e., decision, information, and data) may be involved in a network.

As noted, decisions dictate the types of data that must be assembled within the data system. Let's spend some time discussing the nature of decision making in forestry and then focus on some of the problems involved in deriving information needed for sound decision making. Production decisions will provide a foundation for our discussion and will enable me to illustrate the knotty problems involved in attempting to quantify a qualitative world.

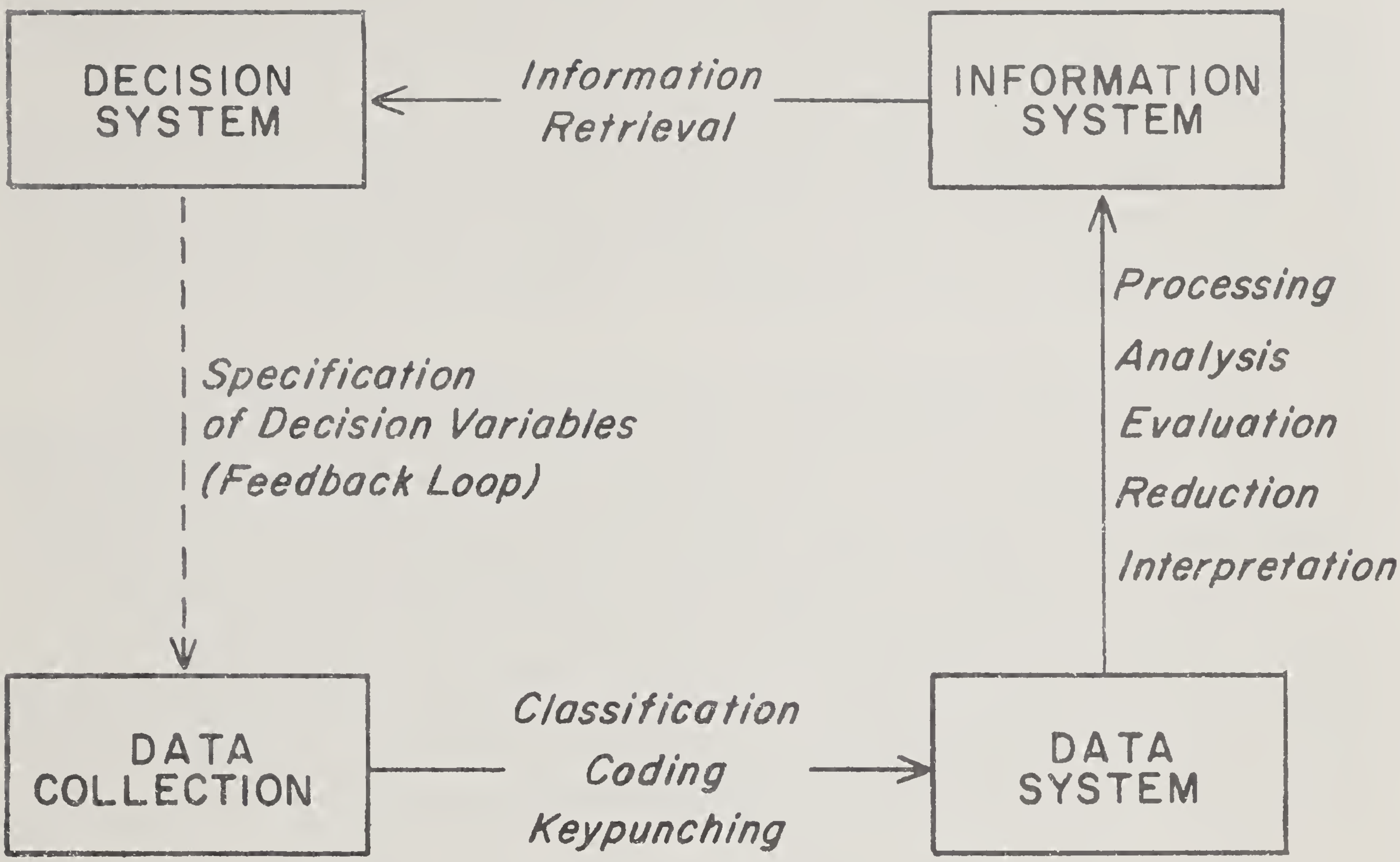

FIGURE 1. FLOWS BETWEEN DECISION, INFORMATION AND DATA SYSTEMS

The central problem for the forest manager is to allocate resources, including forest land, to achieve the goals of his employer. Now, the goals which foresters must attempt to fulfill are highly divergent, depending upon the particular firm involved--private or public, large or small, owner-managed or not, etc. Given that different sets of goals may be involved, it is nearly certain that a multitude of "optimal solutions" to the resource allocation problem should be found in the practice of forest management.

This issue of the firm's goals is the first barrier normally encountered when attempting to model a forestry decision system. Usually it is assumed that private firms are trying to maximize profit, and public agencies are attempting to maximize social welfare. As anyone who has been involved in this type of research effort early discovers, however, both of these commonly-held assumptions are too naive to be very useful in the development of models which are capable of generating management and policy guidelines. Much of the time and effort of the model-builder must be spent in discovering just what is to be optimized--that is, what is the objective function?

When I considered the various types of natural resource data earlier, I purposively omitted the product prices of the goods and services. These are the valuations that society attaches to all goods and services produced by the forestry sector of the economy. Product prices, therefore, may be considered weights. Normally these weights are taken to be market prices.

I wish to spend some time discussing prices because these may not be nearly as "quantitative" as many analysts assume them to be. To investigate this type of natural resource data, it is necessary to explore the nature of pricing decisions.

It is necessary to make a differentiation between goods and services that are priced by a functioning market, e.g., timber and forage, whereas other goods and services are not, e.g., some recreational services.

In order to evaluate both priced and non-priced goods and services <u>in the same model</u>, it is necessary somehow to derive prices for the non-priced goods and services. This requirement has lead to a major line of research and theory-building activities for resource economists, namely that of pricing recreation services or deriving "demand curves." Needless to say, the various methods of deriving values for recreational services has provided many a resource economist with an additional literature citation.

The question is just how do we handle the goods and services for which prices are not established in a functioning market? Do we ignore the problem and concentrate on the priced goods and services? Assume some "reasonable" values? Or do we simulate a market? All of these approaches have been used by resource economists at one time or another.

The approach that many analysts have taken regarding this problem of pricing is to avoid the problem entirely and instead insist that, in the case of the public lands at least, the goods and services <u>other than timber</u> must be offered free to the public because after all, as citizens they have paid their taxes (e.g., in the case of recreational services) or they have traditionally used the public lands as their own (e.g., mining claims, and grazing rights).

On the other hand, many analysts, especially economists, feel completely lost without a market price and attempt to fill this void by either assuming a market price exists or by attempting to simulate a market.

If we ignore the non-priced goods and services we are probably omitting the real growth components within the forestry sector of production. In any event, the effect of this omission is bound to cause a serious misallocation of resources, which will result in over-production of priced goods and services, e.g., timber, relative to the non-priced goods and services. That is, we will produce more timber than is optimal in terms of the satisfaction of human wants. This way of handling the non-priced goods and services is highly deficient on yet another level,

namely that models developed along this line will not prove creditable with the public. It is likely that virtually any "public" will see through resource allocation and management models that omit the non-priced goods and services, or treat them in some trivial manner.

If we decide to assume "reasonable" prices for the non-priced goods and services, the burden is still on the researcher to derive, rationalize and fully justify such values. On the other hand, the use of a range of such "reasonable" prices in a sensitivity analysis using a computer simulation model may prove extremely useful in indicating the importance of the non-priced goods and services relative to the priced ones and may indicate the importance of deriving more exact and accurate "reasonable" prices.

It is necessary at this point to define what is meant by "reasonable" prices. Generally such prices are taken by economists to be those established in perfectly competitive markets. The requirements for a competitive market include: (1) a homogeneous product, (2) buyers who exhibit no preference to a particular seller and vice versa, (3) an adequate number of buyers and sellers so that transactions between any one pair of participants will have no effect on the product's price, (4) no monopoly power or institutional restraints exist, (5) there is full information on the part of all producers and prospective buyers of the product, (6) producers strive to maximize profit and consumers strive to maximize utility, and (7) there is free entry into and exit out of the market for all producers and consumers. (Henderson and Quandt, 1958, p. 86).

It is evident that there are not forestry goods or services that strictly qualify as being traded in perfectly competitive markets. In our model building efforts, therefore, we must recognize market imperfections and indeed must build the structure and incidence of these imperfections into our models. Market imperfections are caused by such factors as collusive agreements or monopolistic behavior on the part of buyers and sellers, institutional restraints, and political power. If we force ourselves to model the price setting process, we will come face to face with the sources of market imperfections.

Regardless of the market structure involved, the model builder must develop weights somehow to apply in an objective function if the "betterness" of alternative policies is to be evaluated. The question remains then, how to come up with a set of unbiased weights?

The method that has been generally followed in solving this problem is to accept whatever dollar prices are available and to simulate a market and thereby derive proxy market prices for non-priced (or non-market) goods and services. These weights then can be used in the allocation model. Various methods have been developed to simulate a market, prominent among these being the Clawson method of deriving a "demand curve" for outdoor recreation.

A more productive and rational attempt by economists, at least in my opinion, is to talk in terms of opportunity costs, e.g., to express the price of recreational services in terms of the timber foregone in its production. Since timber has been the most completely priced product of the forest, it has often served as the currency in these sorts of calculations (e.g., see Rickard, et al., 1967).

If one is not really interested in determining the level of production of non-priced goods and services, but rather is faced with target levels which must be provided somehow, then the problem can easily be modeled as a linear program, with these target levels (i.e., requirements) serving as constraints. In this case one of the outputs of the L.P. model will be the shadow prices of the next unit of production for those non-priced goods and services whose target levels are achieved in the solution.

This type of modeling strategy presumes, of course, that target production levels which enter as constraints were optimally determined. Unfortunately, in order to do this, it is necessary to have determined the weights attached to these activities in the appropriate objective function. There is no reason to believe that target levels have been estimated in this way. In our model-building efforts we must, therefore, forthrightly face this problem of determining the weights or prices to attach to these activities.

The irony of the search for a way to simulate market prices for the non-priced goods and services of the forest is that the so-called priced goods and services are not really traded in competitive markets and hence the prices of these goods and services may not be fully appropriate to an allocation or management model either.

Generally speaking, when we look at the forestry economy--both the public sector and the private sector--we find administered prices rather than prices arrived at by the interaction of supply and demand in a competitive market. Spatial monopolists and oligopolists are found on both the buying and selling sides of the markets, depending upon which good or service is being referenced. This is true of timber to a considerable degree, even though we generally consider this the best example of a priced good within the forestry sector. I believe it is important to discuss why such is the case.

First, we should recognize that timber is not a product. Timber is really a wide array of products, some which can substitute for one another, some of which cannot. Since timber is a producer's good rather than a consumer's good, this means that the number of final products manufactured from wood in a forest may indeed be large.

Second, given that timber includes a wide array of goods, these goods are produced by and large in a small number of plants within any given given geographic area. The very distribution of stumpage insures that timber firms are in most cases best classed as spatial monopsonists or oligopsonists. Very simply, this means that stumpage prices will be administered, <u>even within the private sector</u>. This does not necessarily mean, however, that the final consumer product prices will be administered, since these products usually can be shipped over a wider geographic area and hence be more competitive with other timber products as well as substitutable non-timber products.

The fact that there is a degree of competition in say, U. S. Forest Service timber sales, does not mean that there exists a competitive market, which would permit the use of product prices in an objective function of an allocation model on the macro scale. Stumpage prices are administered prices in that the appraised prices of the various timber species are derived by administrative calculations, not the interaction of supply and demand. Of course, it should be expected that the interaction of supply and demand for the consumption goods produced from the timber will be reflected in these administrative calculations, even if a considerable time lag and change of location occurs. The appraised prices constitute minimum acceptable prices to the seller, the government agency in this case. It is important to note that a sizeable proportion of federal government timber sales are bid on by a single operator and hence are sold at the appraised price.[2]

The appraisal prices for timber set by government agencies are surrogate market prices of a type not greatly different from the prices derived by simulating a market in the case of the non-priced goods and services.

Ironically the government does not seem inclined to utilize this same price-setting process in selling the non-priced goods and services of the forest. This procedure of pricing could likely be applied to a greater extent than it has been, but it has several limitations. First of all, it seems that to be operable it is necessary that the government get out of the business of selling forestry goods and services directly to final consumers, as it presently does in the case of forest recreation. That is, this process is feasible only if the transaction is taking place between the government and a primary producer, such as a lumber producer or a concessionaire at a recreational area.

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2. For an investigation of this relationship in the Pacific Northwest, see Walter J. Mead and Thomas E. Hamilton. 1968. Competition for Federal timber in the Pacific Northwest--An analysis of Forest Service and Bureau of Land Management timber sales. U.S.D.A. Forest Service Research Paper PNW-64, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 63 pp.

Second, the Federal Government does not have control of some of the resources and hence cannot sell them, e.g., fish and game (note, however, that society still expects the federal forest manager to maintain habitat favorable to the production of fish and game even if he cannot sell these products). In cases such as these it would appear that the best strategy for the model builder is to develop target levels (or requirements) that appear to be realistic in light of historical trends of use and treat these levels of use as constraints on the production programs involving the remaining goods and services.

In the case of the non-priced goods and services, especially recreation, researchers generally have been concerned with participation or historical use and projection of usage into the future. In the modeling of such relationships, it is merely necessary to utilize various statistical procedures of parameter estimation which will permit projection of the state of the system at some future date.

This type of modeling falls on very sympathetic ears, of course, because it nearly always indicates higher future "needs" and "requirements" and likely always will as long as population and/or affluence grows. Such projections are must appreciated by the various pressure groups involved in the production of consumer goods and services derived from the primary forestry products, as well as the various government agencies involved in the production of raw materials. The positions of all these decision-making groups are enhanced if projections indicate that their goods and services will be subject to ever-increasing demand.

The problem of developing surrogate prices is even more baffling for water and fish and wildlife than it is in the case of on-site recreation. At least in the case of forest recreation there are fixed geographic locations which may be considered alternative sites of production. However, the production site in the case of water is the entire watershed. Practices involved in the production of other goods and services within the entire basin may well have a great impact on the production of water. This means that to properly evaluate the production of water relative to the other goods and services which may be produced within the watershed, it is necessary to consider the entire watershed as the spatial unit of investigation. Also, there must be a high degree of interaction built into the models of the various subsystems in order to relate impacts from the other subsystems.

Pricing or valuating water production is a difficult task because the ultimate users are far removed from the production site geographically, at least in most cases. Also, water enters as an input to a multitude of production processes as well as being a consumer good (although almost always some treatment is involved before it is used by final consumers and the water treatment must be considered a production process). The importance of water production in the forestry system must be considered in light of these multifarious uses of water by society.

A forestry product such as water which enters into the production and consumption processes of so many sectors of the regional economies and the national economy can be handled only by explicitly tracing its effect on these systems as a whole. This is best accomplished by use of regional, inter-regional, and national impact models. The structure of these models may take the form of the typical Leontief input-output analysis or various types of mathematical programming models.

Since forestry goods and services are produced both by private and public firms within our economy, and an appreciable portion of the goods and services (especially the non-priced ones) are produced by the Federal Government, it is almost certain that prices set by officials of the agencies will be extremely influential in pegging the prices of all forestry goods and services, privately as well as publically produced. This appears to be true even though the Forest Service, for example, decentralizes production decisions somewhat.

Since we are talking about a planned economy when we talk about the forestry economy, the main production question then is just what levels of production for each good and service should we plan on?

Methods of determining the levels of production of all goods and services simultaneously do not exist. Technical men concerned with the physical aspects of producing the various kinds of forestry goods and services (e.g., water, recreation) talk of "needs" or "requirements" without reference to effective demand or the economic aspects of production. Economists have scoffed at this situation and the types of studies which it generates (e.g., timber requirements studies) and call for supply-demand studies in all their neoclassical microeconomic elegance.

Unfortunately, no one, economist or layman, seems to know how to accomplish this in light of the assumptions regarding market structure in the microeconomic models. In fact, it does not appear that any of the critics of the requirements studies know how to improve their economic content to any appreciable degree.

The concept of a "need" or a "requirement" is very slippery indeed. We generally do not attempt as a nation to fully satisfy the "needs" of our citizens. In practice, we satisfy effective demand in the private sector of our economy and provide a minimum or even lower standard of goods and services in the public sector.

We have many tools at our disposal (e.g., linear programming), which will tell us how to achieve production goals and whether in fact they can be achieved simultaneously. However, we do not have tools at hand to tell us the optimal level of each good and service. If we had competitive markets for each good and service, we could solve this problem at least in theory, by using the well developed calculus of marginal analysis. However, it is the height of self-deception to assume that such markets exist when the evidence all around us shows that they clearly do not.

The response of most resource economists and resource managers to this situation seems to be almost identical--pretend that truly competitive markets do exist. If the model builder persists in this facade, then very likely his model will not be validated in that it will not even be able to accurately predict the direction of future trends, much less be able to predict levels accurately.

Since we are talking about goods and services that are priced to a considerable extent by administrative fiat rather than a functioning competitive market, we must consider the pricing decision explicitly in our models. This decision is one of the really important ones in the long chain of decisions faced by resource planners. The best route for the model builder,

in my opinion, is to recognize the realities and include within his model relationships which express organizational structures, diverse organizational goals, lack of communication between actors (i.e., less than perfect information), various types of constraints, uncertainty, and existing long range plans within which short term planning must follow. This means that model builders must become much more concerned with the identity of decision makers and their "territory", political power, market shares, their decision rules, their interactions (including leadership patterns) and their impact on social welfare.

It appears that our production problem closely analogous to the situation faced by planners in socialist countries except in our case it is even more complicated because here the majority of the production of forestry goods and services is controlled by the private sector. Therefore, public planners must plan on production from capacities over which they have little or no control. This complexity may be reflected in our models by the introduction of stochastic variables. However, these may prove difficult to deal with in a realistic model, mainly because of the large number of such variables likely to be needed.

Although the forestry economy is a planned economy, unfortunately for our environment the planning is of a very fragmented sort and tends to lead to unfulfillment of the best laid plans of the planners. Whether this has been desirable or not is debatable and depends somewhat on your political philosophy.

To a considerable extent this comes about because we have been unwilling to accept the degree of centralized control necessary to have coordinated, comprehensive natural resources planning. This is not particularly surprising, however, because the forestry economy operates within a larger system, the total economy, which in this country is best characterized by the label "mixed economy." In such an economy government plans are realized by use of such tools as grants, laws and regulations, various types of administrative standards, selective investment and purchasing by government, etc.

In view of these realities, the model-builder is advised to structure his models so that management strategies are derived in terms of the available tools of accomplishment. Also, an evaluation and control process is needed to judge the degree of implementation of plans and the adequacy of the tools of accomplishment.

We should recognize that a comprehensive job of modeling any complex real world system is likely to require an extremely long time to accomplish and will require, by its very nature, a large number of various specialists, who will have to learn from one another as the group proceeds from one stage of realism to another. A model of the entire system, of course, is not likely to ever be completed in a fully satisfactory form. To a considerable extent this will be true because the real-world system moves too rapidly.

It is important to have a continuous process of model revision as conditions change. It does not appear possible to justify the expense of a comprehensive job of modeling the forestry system if organizations (i.e., government agencies and private firms) concerned with the management of our forestry resources do not intend to use the models on a continuing basis in their planning activities. In fact, although the models will likely be developed by researchers, it seems essential that they be completely adopted by the administrative units, if they are to have real impact on natural resource use and environmental quality.

Although the problem of modeling the system does appear to be an enormous task, I do not believe it is insurmountable. It should be possible, at least in theory, to develop simulation models for the various subsystems of the forestry system which are both spatially and temporally dynamic. These submodels could be developed in modular fashion, in the form of a series of compatible computer subroutines which deal with one or more decisions. Computer simulation models of this type would permit the organization of relevant data and would indicate data deficiencies. Also, by utilizing sensitivity analysis it should be possible to delimit the quantity and quality of data needed

to be collected for the many variables in the system. The computer simulation model can embody various optimizing submodels where they are appropriate and feasible, but maintain the flexibility of the simulation framework elsewhere. Data would be measured in the highest scale possible, but the structure of the model need not require better than nominal scale for some of the variables. Of course, the highest degree of quantification possible should be implemented, to the extent economically justifiable. Finally, by using sensitivity analysis with the model, it should be possible to isolate the really strategic controllable variables, which when combined in various ways constitute alternative management strategies. In this way better guidelines to resource allocation and management could be provided than is possible without analysis.

Given the high degree of complexity involved in forestry decision systems, the high degree of uncertainty, the long production period for timber, the lack of quantification of many of the variables, and the fact that many decision processes defy modeling in mathematical terms, it is likely that decision-makers will have to interact with the model's mathematical structure, if the model to be adequate in generating guidelines useful in planning for resource use. This is, human decision makers should play roles in the model. This requirement has not been as important in the past as it is likely to be in the future. This has not been a problem in the past because decision models have been developed for small subsystems in nearly all cases. As models develop in complexity and include more and more submodels within the same model, it will be necessary to make provision for human interaction insofar as the decisions are of the nonprogrammed variety.[3]

Unfortunately, we have a long way to go in achieving models of the type I have described above. There have been numerous studies which have resulted in models of various subsystems of the forestry system, but by and large these are not modular and hence cannot be fitted together. It appears that the only way to remedy this situation is to have better coordination among researchers and large research projects which are designed specifically to produce compatible subsystem models.

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3. For a discussion of programmed and nonprogrammed decisions, see H. A. Simon. 1965. The new science of management decision. In the shape of automation for men and management. Harper & Row, pp. 57-79.

Consider the state of affairs of a forestry subsystem that has been the subject of scientific investigation in this country for over 70 years--timber. The truth of the matter seems to be that timber production models are still very primitive, especially those relating to uneven-aged mixed species stands and those relating to intensively-managed stands on short rotations. Given that these models leave a great deal to be desired, it is not at all surprising that some of the subsystems that have more recently been the subject of investigation are at a very rudimentary stage of development.

Many of the models that have been developed have not included controllable variables, hence are not appropriate tools for policy analysis. A solution to this problem is to have researchers work more closely with managers and policy makers so that they would have a better appreciation of the variables that are appropriate components of management strategies.

A rather neglected phase of the modeling job concerns the actors involved in the real-world processes. Who are the decision-makers and how do they interact? As we all recognize, in the field of natural resources there are many areas of conflict between various organized groups. What kinds of linkages connect these groups in the decision-making system? If we were able to realistically model these real-world situations, it should be possible to examine the possibilities of deriving strategies that will mutually satisfy the actors' goals. To some extent this type of modeling is similar to the market analyst's task of indicating product flows between producers and consumers. This job is more difficult, however, in that what is really needed is to simultaneously indicate the complete maze of decision-makers involved in each decision.

An additional problem in modeling a multiple use system is that the production period for the various goods and services varies widely. Some products, for example timber, are produced over a long period of time from generation until harvest of the final crop (rotation period), whereas other products, for example

recreational services, are "produced" over a very short period of time, in fact, almost instantaneously. In view of this disparity, it is essential that the temporal dimension and the interrelationships between the production periods for the various goods and services be an integral feature of the forestry system model. Unfortunately, few of even the single product models which have been developed for the forestry system fully consider the production period explicitly, or the dynamics of production and resource use.

It is essential that the spatial dimension also be an integral feature of any forestry system model. The production of forestry goods and services requires large areas of land per unit of consumer product, but the amount varies a great deal between the various goods and services and even between different sources of raw materials used in the same production process.

The spatial dimension is required in the models to account for a number of important factors. One which has been fairly significant in forestry research is the geographic distribution of tree species. As products derived from forest stands vary somewhat according to the species involved, it is important that models include this biological feature.

A second related biological and physical factor is the fertility differentials of forest sites over space. Insofar as there are any spatial regularities (i.e., fertility zones) it is essential that these relations be embodied in allocation and management models. Although foresters normally look at this factor in terms of vegetative growth differentials, it is also possible to subsume under this factor esthetic differentials which occur as a consequence of differentials in vegetation, climate, topography, etc.

Another important spatial factor which must be included in forestry system models is some method of handling the transportation system. The location of the transportation networks relative to the location of forest stands is an absolute requirement of the models because otherwise it would not be possible to properly valuate forests in terms of their access for multiple uses. In terms of modeling strategy, it may be best to build a transportation submodel separate from, but modular to, the other subsystems. In the transportation submodel all aspects of access to the environment for human activity should be included.

Finally, an important institutional spatial factor which should be included in any forestry system model is the land ownership pattern. This information can provide the linkage of the land with decision-making groups. By characterizing owners of forest land by socioeconomic features, it may be possible to build into the models predictions of group decision-makers' behavior, including responses of one group to policies of another.

In the case of the forestry system, we still do not have very good information regarding the production possibilities for various combinations of goods and services. Information of this type which reflects productivity over time of the various spatial units is absolutely necessary if managers are to be in a position of satisfying the goals of their private firm or public agency.

It is essential that models of the forestry system include consideration of the impact of forestry management practices on the state of the environment. It is important that both the positive and negative impacts be recognized. Too often in recent years negative impacts have been highlighted to such extent that positive impacts were nearly forgotten. This may be just a case of the pendulum swinging from the almost complete neglect of the negative impacts (or externalities) to the opposite extreme.

Surprisingly, few truly operational models have been developed to assist decision makers operating within the forestry system. Of those models that are operational and at least potentially helpful to forest managers, few intergrate the maze of decisions faced by managers and policy makers, or consider the sequence of decisions and their interrelationships. In the available models, usually just one or two decisions are included. Decision systems are typically much more complicated. Most of the available models are of the static or comparative static type, whereas decisions occur in a dynamic framework. Most available models relate to a single point in space, in the tradition of neoclassical micro-economic analysis, and thereby fail to consider the spatial interrelatedness of human activities. Most available models fail to identify the structure of decision making groups and hence omit from consideration the impacts of

economic and political power on the decision rules of these groups. These omissions no doubt make the models more generalized than would otherwise be the case. However, these omissions affect the applicability of the model. Policy guidelines generated by the models may not be considered relevant to <u>any</u> existing decision making group and are likely to remain unused. This is not meant to infer that such models are not useful in contributing toward building theory.

It would seem that the above criticisms of published models argues for model building within decision making groups rather than for the formulation of generalized models which have traditionally been the primary interest of the economist. On the other hand, I realize that the type of modeling that I advocate has been going on for many years, especially in the private sector of the economy, but is rarely published. I hope that we will see an expansion within the public sector of this type of modeling because the stakes in reaching good decisions are much higher here than in the case of the private sector. First of all, the size of the enterprise is vast. The decision making group is large and virtually every citizen is a stockholder. The product mix is larger in the public forestry enterprise than in the private forestry enterprise.[4] Many goods and services produced by the public sector are not priced in existing markets, hence the valuation problem is severe, causing serious difficulties in making resource allocation decisions. In addition, in the public sector it is more important to be concerned with the production of "bads" as well as "goods", since the potential for environmental disasters is so very great. This condition flows largely from the large sizes of the enterprises in the public sector as compared to the average in the private sector. Bad forestry policies on the part of a small firm (by "bad" I mean they result in serious negative externalities) may have a negligible impact on environmental quality, human health and social welfare. The same practice on the part of a large government agency may result in a regional disaster, including serious health hazards and numerous lives lost.

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4. Note that I am referring here to the mix of primary products of the forest, and not products that are manufactured using these products as raw materials.

What does all this mean in terms of model building? It seems that models of the forestry system will be exceedingly difficult to devise if it is necessary to embody within them all the complexities that I have mentioned here. In fact, it may be that model building efforts of this magnitude are not even possible at this time. This could be so for many reasons; (1) the lack of multi-disciplinary teams of scientists broad enough in orientation to develop such models, (2) deficiencies in knowledge of various subsystems to the extent that not even the most primitive models could be built, (3) a lack of data that could be used to calculate the parameters of models even if they were developed, (4) serious measurement problems, particularly in the case of the forestry services, which may well have the effect of causing us to produce too little of them, (5) a lack of mathematical and statistical techniques capable of manipulating complex multi-dimensional systems models in an efficient manner, and (6) considering the likely size of the idealized model we would have to admit the possibility that no existing computing system is capable of handling the computational load in a reasonable time period and at an acceptable cost.

In addition, if we are interested in improving decisions involving the forestry system, then we must be concerned with the adoption and use of the models by decision making groups. Models that have been developed thus far have not had a favorable adoption rate, at least in my opinion. This may be due to certain of their deficiencies, some of which I have noted. On the other hand, perhaps they are not being adopted because of a breakdown of the linkage between researchers and decision makers--what we normally term the "extension" function.

It appears that models are difficult to communicate from researchers to extension agents and decision makers. In most of the sciences, models do not need to be communicated to decision makers, as the clientele of a model building study is not the decision makers, but rather other scientists. This is not true, however, of policy science. In policy science, models are developed to provide guidelines to decision makers and not just to communicate ideas to other scientists. If we are to achieve success in model building efforts in resource economics, therefore, it is essential that we provide a mechanism for

transmitting these theoretical constructs to the people who can make use of them in solving problems. At the present time I do not think we have a workable channel and the small amount of adoption that is occurring is largely due to individual model builders playing an extension role in addition to their research role. This may be the most desirable way of handling the implementation phase. However, if it is, then we should evolve organizations which function this way.

Computing systems have played and will continue to play important roles in improving decision making in natural resources. Referring back to the diagram which illustrates the relationship between the data system, the information system and the decision system (Figure 1), note that the computer may be involved in the operation of each of these systems. Computing equipment can play an important role as storage media for both data and information. With the development of large capacity storage devices (e.g., disks, drums, fixed head storage, data cells, etc.) which may be rapidly accessed, the maintenance of large multi-dimensional systems becomes feasible.

Computing systems, although already important contributors to progress in forestry, could prove much more important in the future. It appears that by and large the principal uses of computers in forestry have been in routing statistical and analysis by researchers, and in providing improved accounting reports for administrators. At least two areas of insufficient development are evident: (1) the application of computing systems by management analysts in comprehensive management systems models, which could be expected to result in better decisions (i.e., decisions more likely to satisfy the firm's goals), and (2) the application of computers in the less quantified areas of resource management and resource research.

Computers can provide an important organizing function in any management organization. An example of this is in the area of management information systems. In this rapidly changing world with the characteristic information overload and saturation, it seems to me that the only hope for efficiently utilizing information lies in automated retrieval systems. Of course, it is true that there are many difficulties in developing such systems, particularly with multi-purpose, multi-user systems. For example,

there is the problem of keyword selection. However, the need for such systems to assist decision making units is fairly clear. In fact, without an automated retrieval system, oftentimes decision makers will find it impossible to marshall the relevant information in time to apply to critical decisions.

Information systems can be computerized and retrieval systems may be developed to assist managers in making either programmed or nonprogrammed decisions. Decisions of the programmed variety may be computerized where it is of benefit to the firm, and information systems may feed information into decision systems. Data systems may be computerized so that data may be retrieved, reduced, and subjected to statistical analysis efficiently. Once data have been processed into information, information elements may be stored in a computing system and rapidly retrieved for use in decision making.

Computers long have been employed in the various operations involved in deriving information from data. A good example from forestry research is the tremendous amount of statistical analysis that has been accomplished using computers.

When we consider the applications of computing systems in forestry research, we normally think in terms of processing what is often termed "hard data"--that is, data measured in the more quantitative scales (e.g., interval and ratio scales). It is probably true that the vast majority of the computer runs that have been completed are of this nature. Many of these applications have been statistical and have involved tremendously large amounts of data and the analysis of a multitude of variables--analyses which would have been prohibitively expensive, both in terms of time and cost before the introduction of the high-speed digital computer. These types of applications, which likely would never have been attempted prior to the digital computer, are now routinely completed at extremely low cost, and the cost of this type of work continues to be reduced as computer technology advances.

Frequent examples of these types of analyses include multiple regression analysis in the area of estimation statistics and t-tests in the area of test statistics. Needless to say, payoffs from these types of applications have been very important in forestry (e.g., development of tree volume equations). Often it is assumed that if computing equipment is to be used it is necessary that all data be quantitative. Such is not the case, however. As a matter of fact, one of the least exploited opportunities for using the computer in decision making is in areas where measurement is only qualitative. The potential for the use of computing systems in cases such as these are great because normally it is not possible to process the data to the extent that it is possible with the more quantitative scales.

Once one accepts the idea that computing systems can be useful in the analysis of data in the less quantified measurement scales (i.e., nominal and ordinal scales), it becomes evident that a very broad range of forestry problems may be scientifically analyzed which have not been approachable in the past. An example of this is the opportunities for bringing the spatial dimension of forestry production and consumption into focus, as in the case where data consists of geographic locations of wood processing plants. There have been some applications of computer mapping techniques in forestry but the surface has just been scratched.[5] Another very important area which has been much neglected is consumer preference research, where measurement in the ordinal scale is common.

As noted earlier, it is important to do more in the way of analysis with variables measureable only in the less quantitative scales because our allocation models are seriously deficient when they ignore these variables, as is presently the case to a large extent. To achieve optimal allocation, it is necessary to have <u>balanced</u> models which consider the broad range of management alternatives, and not just relationships that are easily quantified.

To achieve the type of comprehensive planning that I have outlined may well require additional progress in computing systems technology. I do not believe, however, that technology is the principal barrier to improved decision models and better comprehensive planning. Rather, the principal barriers are likely to be non-adoptive behavior on the part of managers and inflexibilities and rigidities or the part of institutions.

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5. See, for example, the work of Amidon (1964 and 1966).

For many years now society has attacked the non-adoptive behavior problem with vigor through various progressive educational activities. Unfortunately, such activities have little impact on decision-making if managers return to a decision-making environment so restrained by institutional framework that they are unable to put their education to good use. In fact, they may simply become frustrated and would have been better off without the additional educational experiences. Such conditions call for a restructuring of institutions, a process which requires much organized effort and usually the passage of a considerable amount of time.

All of this is not to say that change is a good thing in itself. Such is surely not the case. Proposed changes must be tested, retested, and put on probation. However, if the one good proposed change in 20 or 100 cannot be implemented because "that is the way life is," then the decision system must be considered decadent and ripe for a complete overhauling or replacement. It is my belief that such is the case in many areas of resource management.

Literature Cited

1. Amidon, Elliot L. 1964. A computer-oriented system for assembling and displaying land management information. U. S. Forest Service Res. Paper PSW-17, Pacific SW. Forest and Range Expt. Sta., Berkeley, Calif., 34 pp.

2. Amidon, Elliot L. 1966. MIADS2...an alphanumeric map information assembly and display system for a large computer. U. S. Forest Service Res. Paper PSW-38, Pacific SW. Forest and Range Expt. Sta., Berkeley, Calif., 12 pp.

3. Henderson, James M. and Richard E. Quandt. 1958. Microeconomic theory: A mathematical approach. McGraw-Hill Book Company, Inc., N. Y., 291 pp.

4. Holm, Paul L. 1968. Data systems and information retrieval adaptable to water resources. In Dean T. Massey and Gordon D. Rose. Opportunities for regional research on water resource problems. Monograph 10, Ag. Law Center, University of Iowa. pp. 108-129.

5. Mead, Walter J. and Thomas E. Hamilton. 1968. Competition for Federal timber in the Pacific Northwest--An analysis of Forest Service and Bureau of Land Management timber sales. U.S.D.A. Forest Service Research Paper PNW-64, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 63 pp.

6. Rickard, Wesley M., Jay M. Hughes, and Carl A. Newport. 1967. Economic evaluation and choice in old-growth Douglas-fir landscape management. U.S.D.A. Forest Service Research Paper PNW-49, Pacific Northwest Forest and Range Expt. Sta., Portland, Oregon. 33 pp.

7. Simon, H. A. 1965. The new science of management decision. In The shape of automation for men and management. Harper and Row, New York, pp. 57-79.

COMMENTS ON DANIEL E. CHAPPELLE'S PAPER "QUANTITATIVE ANALYSIS IN A QUALITATIVE WORLD: MODELING FORESTRY SYSTEMS TO IMPROVE DECISION MAKING"

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As an overall comment, I agree with the general thrust of Dan Chappelle's paper and feel that the flow concept in his Figure 1 is worthy of study and understanding before anyone tries to computerize any decision-making system, even in part.

Before considering how best to use quantitative methods, we must remind ourselves that "going quantitative" in decision making can expose us to certain logical traps, inconsistencies, and false conclusions, unless we are careful and understand our implements well. Some of these traps are:

1. <u>The tendency to overlook or minimize the importance of unquantifiable factors</u>. Chappelle has emphasized this in noting, at some length, the problem of the price of non-market forest commodities.

2. <u>The tendency to ignore absolutes</u>. Items that cannot be put on a scale may frequently be omitted, even though they are of vital significance. Such factors as life, death, sickness, legal liability, and pregnancy, are examples of some of these absolutes. The philosopher of programmed decision-making, Herbert Simon, has said frequently that the ultimate criterion of success is survival.

3. The subconscious assignment of value to location on a numerical scale. There is frequently the assumption for factors that can be put on a numerical scale, that if some is good, more is better, and too often the highest obtainable is best. This applies to such factors as levels of profit, levels of soil fertilization, stocking levels in forest stands. Anyone who remembers the long struggles over the problem of "normality" in forest yield estimation will recognize this hazard.

4. Invisible weighting. At times, in an effort to become quantitative, we may put factors on scales estimating their value from 0 to 100. Worse still, this may be followed by an averaging process. Sometimes we assume objectivity by refusing to put different relative weights on different factors. However, if all factors are placed on the same scale, they are automatically given the same weight, which in itself may be a biasing decision when we know the factors are not in fact equal.

5. Favoring ratio scales over nominal or ordinal scales. Prof. Chappelle himself falls into this trap saying, "data should be measured in the highest scale possible, but the structure of the model need not require better than a nominal scale for some variables. Of course, the highest degree of quantification should be implemented". He is in good company in this opinion, for it is also expressed in many books on research methods, but ratio scales may imply unreal degrees of accuracy.

6. Being forced to digitize. In order to enter data, we are frequently required to make this data digital in form. Sometimes, there may be definite and supportable evidence for differences that may be shown in rankings, which differences will not support the placement of a digital value.

7. Worshipping at the altar of optimizing. Once we have a model, there is a tremendous temptation to try to optimize certain variables within that model. Further elaboration here is not necessary; we are all familiar with the pitfalls of trying to put a razor's edge on a sandstone.

Although not a specific pitfall as such, anyone doing much mathematical modeling must be careful to avoid the temptation to use numbers to draw around himself an aura of objectivity on matters which may involve considerable subjective decision making.

Despite these caveats, I endorse the major points made in this paper. The diagram in Figure 1 is very helpful. It emphasizes the circularity of the decision process showing the importance of feedback in continually improving decisions. This cycle suggests that the attainable degree of optimization depends on the speed of cycling of the entire system. Rapid feedback permits closer control. Furthermore, if the cycling of the system is fairly rapid, detailed measurement of the variables may be less important than where the cycling is very slow.

Chappelle stops short of suggesting that the entire decision system can be computerized, in which we would all heartily agree. At the present time, it is probably more important that we move back in the use of the computer toward improving the data acquisition part of the cycle rather than moving forward toward using the computer in the ultimate decision system. Most decisions require a mixture of quantitative and qualitative information. The proportions of these may vary in different situations, but there is almost always a modicum of qualitative information. Ten years ago there was much written about the "automatic factory", but these seem to be relatively slow in arriving. As Giles stated in his paper, ultimately people must set the purposes of the entire system. And as other theoreticians on systems and decision making have pointed out, a decision is never ultimately "made" until it is actually implemented. This commitment of resources may get quite outside the system diagram given here.

This paper may be too much concerned with the possibility of making a global model of an entire forest system. Efforts at making global models generally become impossibly ponderous for the computers, programming skills, and data sources which

are available. The logical start is modeling and computerizing small pieces which may eventually fit together. More value may be had at the present time from computerized models by using them as training tools, both for students and for active managers, than using them as a decision maker in themselves. Bruce Bare has given an example of this use of the model. A manager may be greatly helped by use of the model to appreciate the interaction of complex parts of a system, and by understanding how seemingly disconnected parts can effect a final outcome. Such appreciation may greatly benefit a qualitative decision. As Fortson has suggested, what we are after are "insights, not numbers".

As I read Chappelle's paper, I cannot avoid making the suggestion that we need much more study of decision-making methods by other than the classical market exchange model which the economist has so thoroughly elaborated. There is the suggestion here of dangerously biasing governmental decisions by trying to force them into the same model of the free-enterprise market decision. Other areas of currently observable decision making might well deserve detailed study. What are the methods by which teams make decisions in an athletic contest? How do groups attack the job of developing a large project that is outside the area of business competition, such as that of planning a National Meeting for the Society of American Foresters? How do individuals make the decision that ultimately controls their expenditure of leisure time? By exploring such questions we may formally recognize some decision models quite different from the maximizing of net profit, minimizing of loss, or maximizing of present net worth.

In conclusion, my prognostication is that we will continually strive to be more quantitative and to improve the man-computer interaction. However, we must be cautious in interpreting results and committing ultimate decisions to the computer along. Impressed and overawed as I am at its fantastic capabilities, I am always brought back to the realization that it is just an extraordinarily high-speed number cruncher.

INTRODUCTION TO SESSION ON APPLICATIONS

Kenneth D. Ware
Forest Service

In the previous papers the authors have explored important general background and provided prognosis of the future of computer and information systems in resource management of their general topics that are of significance to resource management decisions rather than to computer or information science. They have attempted to help us foresee what these sciences may provide of future value in management decisions.

These have been good reviews and previews of the state of affairs in: (1) the general rule of computer systems; (2) the often-rocky road to efficient, timely, adequate access to computer-systems with substantial suggestions for future improvement; and (3) the difficult job of bridging that mire between the view that all will be obvious when we have it all quantified, and the view that it is such a basically qualitative world that quantitative analysis has no value.

In a workshop on a topic of such breadth it is difficult to decide which particular examples will be most useful to illustrate what is possible. There are many examples that might be selected, and it is unlikely that any one example will itself be directly useful to more than a few of the audience. Nevertheless, the authors of the papers that follow have accepted the challenge to make particular applied examples illustrative of some details and of general ideas as well.

First, Dress sketches a framework for those that follow, and provides a transition mode from the earlier general papers to the specific examples. His framework draws a parallel between scientific methods and the "operations analysis" or operations research mode to show how computer and information systems relate to management decisions. He traces a path from decisions back to models and then to computer systems via operations research.

In his information-packed paper, Otterbach then gives examples of sub-systems and describes how these sub-systems relate in a computer and information system for an industrial organization. An important feature of his paper is the implied evolution of the systems and applications and the indication of sophisticated examples that cannot yet be unveiled. Otterbach adds reinforcement to the framework built by Dress, systems approach.

Then as an example of applications Bare takes the area of management gaming. He outlines the uses of such gaming and sketches some specific games, indicating their role in understanding decision models and familiarizing decision makers with the role of computer-based information systems and feedback. Next we learn from Turner of developments of management information systems and related examples in Australia. And finally Harvey discusses an information retrieval system for research scientists. The example is of a class important to professional resource managers, because it is clear that the rapid and efficient retrieval of information and data are important aspects of managerial decision modeling and feedback as outlined by Dress.

FROM REAL SYSTEMS TO COMPUTER SYSTEMS TO DECISIONS

Peter E. Dress
Pennsylvania State University

The purpose of this brief paper is to provide a general framework for the more specific papers to follow in this afternoon's session. This framework will be developed by exploring the close parallel between traditional scientific methods and the quantitative methodology of modern management science. The explicit intent will be to clarify some of the terminology of operations research and to illustrate the goals and directions of systems analysis as applied to problems in natural resource management.

I have chosen the scientific method as a vehicle for this comparison since education in forest resources usually emphasizes the biological sciences (some would claim at the expense of the management and social sciences) and most foresters are reasonably familiar with research methods as developed in this scientific framework. We shall see that there is a distinct parallel between the logic of this scientific methodology and the strategy of management science. Recognition of this parallel is of vital importance if the necessary communication between the areas of technical forestry and forest resource management are to be developed. It is my contention, and I believe the implicit contention of all speakers involved in today's program, that such communication must be established if forestry is to expand from its traditional base and remain a viable human endeavor with net benefits to mankind.

While we are indeed making a partisan plea here for the further development of a holistic resource management approach, it is important to stress that we do not advocate ignoring the relevant features, biological or otherwise, of the systems that we propose to manage. Quite the opposite! But if we professional resource managers continue to be occupied with the fine structure of biological systems to the exclusion of considerations of social demands, it seems obvious that we will pay a high price for our pleasure. This price is the cost of defaulting natural resource management decisions to others who may be far less technically qualified than are professional resource personnel.

The Scientific Method and Management Science

Scientific Method

While there are probably as many "scientific methods" as there are scientists, all valid research philosphies contain certain common and ideally ordered elements.2/ Research of any kind logically begins with problem definition and hypotheses formulation in a general sense. Next, the system under study and the conditions for this study are defined for the purpose of experimentation, exploration, and observation -- this is basically the experimental design phase.

Once appropriate experimental conditions have been developed, it is usual to formulate an analytical model representing experimental outcomes as functions of experimental variables, both controlled and uncontrolled. The model, at least in general terms, should be well in mind during experimental design to insure that the design be appropriate and efficient; although often the final model cannot be constructed until the design is complete. An important additional aspect of the design stage is the reformulation of experimental hypotheses in terms of the parameters contained in the model.

2/ This brief discussion of "scientific method" is developed from the viewpoint of biological research on the grounds of appropriateness. Other formulations are, of course, possible; but the differences lie principally in degree of emphasis. For example, in physical science research the role of modeling is often much more predominant and active than in traditional biological science.

With experimental design and model well in hand, experimentation can be carried out and data can be collected for analysis and interpretation. The experimental hypotheses are tested and either tentatively accepted or rejected. New formulation, experimentation, analysis and verification begins anew. The concepts of hypotheses formulation, tentative verification from empirical evidence, and feedback are omnipresent and essential aspects of natural science.

Management Science

Applications of operations research methodology to the problems of management begin and proceed in much the same fashion as the general scientific method discussed above. First, the management problem must be defined and stated in terms amenable to objective solution. This stage might ideally consist of a verbal statement of management objectives and a description of the restrictions operating on the system and on the decision maker to define what will be called the set or space of feasible decisions. The formal role of hypotheses construction is less evident here than in the traditional scientific method, but nearly always implicit is a hypothesis of agreement between the to-be-developed decision model and the actual decision process. As we shall see, it is this implicit hypothesis that provides the basis for feedback in the "management science method."

Again paralleling the scientific method, the next step in the operations research method is the delineation or definition and description of the system being managed and the subsequent construction of an appropriate systems-decision model. It is this aspect of operations research which is often called system analysis and, while hypotheses formulation might be less explicit here, model building receives considerably more direct attention than is often the case in biological research. A model, as the term is used in this context, is simply an abstract representation of a suitably defined real system.

Once an appropriate model has been developed for the situation at hand, data collection must proceed to obtain that information required to complete the model. A possible point of departure from customary scientific procedures may

arise here. Formal and rigidly designed experimentation will often not be possible in systems management situations because of pressures to continue uninterrupted day-to-day operations or because of the scale of the system. This difference is really only a technical difference, however, and procedures of many types have been developed to facilitate the modeling, data collection, and parameter estimation processes under such circumstances.

Decision Models or Optimization Models

It is quite common that operations research models take the form of mathematical optimization models; for example, a typical problem might be expressed formally as

optimize (maximize or minmize) the function

$$Z = f\ (X_1, X_2, \ldots, X_n)$$

where the $X_1, X_2, \ldots, X_n$ must be chosen so that the system of constraint equations

$$g_1\ (X_1, X_2, \ldots, X_n) = 0$$

$$g_2\ (X_1, X_2, \ldots, X_n) = 0$$

$$\vdots$$

$$g_m\ (X_1, X_2 \ldots, X_n) = 0$$

is satisfied.

In this formulation or model the X_i are independent variables (systems inputs and other decision variables such as time, spatial location, etc.) which are related to systems output Z through the function f $(\cdot)$. The functions g_1 $(\cdot)$, g_2 $(\cdot)$, ..., g_m $(\cdot)$ taken together as a system of m equations in n unknowns quite simply serve to define mathematically the set of feasible decisions or strategies. Technically, it is usual to refer to a set of values for X_1, X_2, ..., X_n as a <u>strategy</u>. A strategy which satisfies all problem constraints (here the system of equations g_1 $(X_1, X_2, \ldots, X_n) = 0$, $i = 1, 2, \ldots, m$) is said to be <u>a feasible strategy</u>. A feasible strategy, say, X_1^*, X_2^*, ..., X_n^*, which optimizes Z in the intended sense is said to be an <u>optimal strategy</u>. In general, optimal strategies may not exist (either the set of equations is inconsistent--the problem is overconstrained--or Z may be unbounded--the problem is underconstrained) or there may be alternative optima. That is, Z may take on its optimal value on more than one feasible strategy.

In nearly all practical situations, the symbolic model expressed above will be assumed or hypothesized to take some special general form; f $(\cdot)$, g_1 $(\cdot)$, ..., g_m $(\cdot)$ might all be assumed to be linear functions of the X_j. If this is the case, we have the well-known linear programming model.

However, regardless of the explicit form of the model, numerous subordinate relationships and coefficients or parameters are usually involved. These relationships and parameters--cost, technical, and structural coefficients--must be estimated or otherwise determined from analysis and observation of the real system. For example, "production functions" which give the relationship of the output Z, to some subset of the input variables, X_i, may have to be estimated from empirical observations. It is at this point in the application of operations research procedures that sampling, designed experimentation, and data analysis become necessary. Once such experimentation and analysis have been carried out, the decision model can be regarded as complete up to and including estimates of model parameters. Then suitable mathematical procedures can be employed to select optimal strategies. This completeness is, to be sure, a tentative matter and

decision models are generally held in much the same sense as hypotheses or theories are taken in conventional science; i.e., they are subject to continual revision. Subsequent analyses, in the forms of sensitivity analysis and decision application, for example, may well indicate that, in fact, the model is not well suited to the task at hand. In such cases the model must be revised or estimates of model parameters must be refined or both; provided, of course, that the benefits anticipated from the use of the improved model outweigh the costs of such revision. The results of this final stage of modeling and decision analysis will generally form the basis for feedback and subsequent revised system analysis. Like conventional science, the elements of model formulation, verification, and feedback are essential to any sound operations research approach to management problems.

Feedback

It will be obvious to any practical problem-solver, whether experienced in scientific research, operations research, or more down-to-earth practical situations, that neither the scientific method nor its operations research parallel usually proceeds in as well-ordered and linear fashion as the previous discussion would seem to imply. Major and minor information feedback loops usually occur at many stages in the process and we are often required to make adjustments or revisions in a myriad of ways. For example, we may find that as model construction or experimental design ensues, the original statement of the problem is not sufficiently precise to permit rational decision making at these stages. Or, to consider another example, we may find at the analysis stage that the sampling plan was inadequate and further data must be collected before we can proceed.

But, in any such systems analysis, we are following the general pattern of a reasoned method of scientific investigation and departures from the ideal linear flow do not matter, so long as these departures are not of a form so that final results are biased or inadequately qualified. In fact, if one considers appropriate individual sub-problems of any major problem-solving effort, he will find that ideal formulations of the scientific method can be followed for these sub-problems.

Literature Cited

1. Ackoff, R. L. 1962. Scientific Method. J. Wiley and Sons, New York, N.Y.

2. Beveridge, W.I.B. 1950. The Art of Scientific Investigation. Modern Library Paperback, Random House, New York, N.Y.

3. Hillier, F. S. and G. J. Lieberman. 1967. Introduction to Operations Research. Holden-Day, Inc., San Francisco, Calif.

4. Poincare, Henri. n.d. Science and Method. Dover Publication, Inc., New York, N.Y.

5. Stoltenberg, C. H., K. D. Ware, R. J. Marty, R. D. Wray, and J. D. Wllons. 1970. Planning Research for Resource Decisions. The Iowa State University Press, Ames, Iowa.

6. Wagner, H. M. 1970. Principles of Management Science. Prentice-Hall, Inc., Englewood Cliffs, N.J.

PLANNING, SYSTEMS, AND PEOPLE

Paul J. Otterback
International Paper Company

The Corporate Setting

The operations of the International Paper Company are indeed quite large. The Southern Kraft Division of the Company has activities in each of the southern states from North Carolina to Texas. The International Paper Company's southern operations include eleven, soon to be twelve, pulp and paper mills as well as pole, stud, plywood and particle board plants. The volume of roundwood and residues used approaches seven million cords and comes from many varied origins across the south. The wood is transported to the plants by truck, rail and barge using Company and non-Company systems. The forest lands of the Company provide a base for many operations. Of the total 4.8 million acres in the South over a million acres support planted or direct seeded stands. The Woodlands Department of the Southern Kraft Division (SKD) has the responsibility for all logging and for managing the forest lands.

The task of logging and managing the many many different types of forest lands has enough complexities to tax any forester's decision-making abilities -- and only through sound decision making, based on the right data and forecasts, can the logging and managing task be successful. The emphasis on people - the forester - is valid because of the varied opportunities which constantly require appraisal. Opportunities such as:

Can we divert wood from Panama City Mill to Mobile Mill and save some money now rather than building inventory at Mobile?

Should we open a woodyard in a certain fringe area to harvest Company lands now instead of searching for chip contracts in the same area?

Which lands should have the longest rotations to take advantage of a possible new market in logs?

These four questions are just the smallest sample of questions which need answers in order for operations to succeed.

I mentioned the word "complexities" to describe SKD Woodlands operations. I think the big question for our foresters is: How do we get a handle on enough of the "complexities" so we can overcome them and can get enough meaningful facts, interpretations and evaluations in order to make rational decisions?

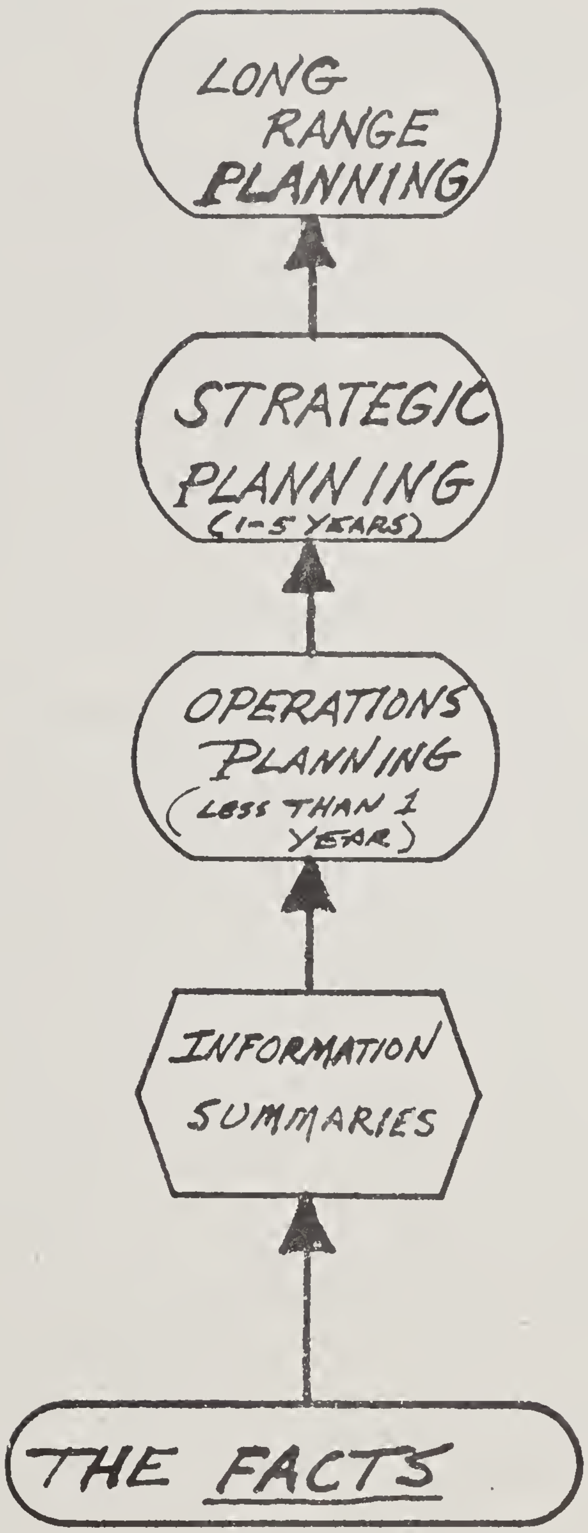
I am going to spend the next minutes with you trying to explain how we attempt to obtain facts and use them in different systems or models to help the decision-making forester choose a valid plan of action. I hope you will also see how the forester relates to the computer and which management science tools are used.

Figure 1 illustrates the flow of information through an upward process from information summaries to use in operations, strategic planning and long-range planning. What is not shown are the systems for using the data in the three planning levels. These systems for the most part are models of various segments of our business. Some models are mathematical programming systems to find the least cost supply of wood or the most profitable harvesting schedule in terms of growth and dollars. Other models are logical flow models in terms of cash or percent growth rates or production rates.

Defining the Terms

Before I begin discussiong the planning systems we use, I should define two terms - models and mathematical programming. A model is a scaled down replica of the real thing. My son

FIGURE 1


LONG RANGE PLANNING
STRATEGIC PLANNING (1-5 YEARS)
OPERATIONS PLANNING (LESS THAN 1 YEAR)
INFORMATION SUMMARIES
THE FACTS

and I build and fly model rockets. The scientific laws governing the flight of actual rockets apply to the model rockets so that the model's design must be such that the true flight can be simulated - the model acts in a general way as the true-life rocket acts.

A model can be made of a segment of business or a forest by the use of mathematical expressions. For example, a barge system can move a maximum amount of wood a week; i.e., a given system has only so many loaded barges or empties and can make a certain number of trips per week. An equation could be written to explain the production restriction of the barge wood system on a number of barge landings. Thus, the sum of the production at yards X_1, X_2, X_3, X_4 and X_5 cannot exceed the carrying capacity of the barge system.

By putting together a series of equations, a model of several segments of a business can be produced. The more variables or equations used to describe the segment the more realistic the model becomes. In other businesses, some very complex models have been built to attempt to see the effects of changing transportation schedules, or prices or production rates. Models are used to test a strategy before going into actual practice in the real world.

Mathematical Programming in my terms is a computer-based technique which finds the optimum solution (either lowest cost or highest profit) for a series of quasi-equations which, in essence, are a model of a portion of a business or system. One older form of Mathematical Programming is linear programming. The advent of third generation computers and software increased the scope of the older L.P. packages so that the term mathematical programming is now rather widespread.

Getting back to the main stream of this talk, we are going to travel up two avenues: one in forest management and the other in wood procurement. Hopefully, we can bring the two roads together and along the way tell you how the forester fits in the picture.

First go back to Figure 1 and look at the bottom, the lowest box "THE FACTS". The facts are the key to making decisions. When we have talked to our own foresters in the past we flash a giant "YOU" on the wall - because we get the facts from our foresters , accountants, our people. The YOU's are the beginning point in all of our systems. In fact, we preach on the idea that our information systems, models and solutions are based on YOUR data and therefore the answers are YOURS. We do not change field data without going back down towards the beginning point to get corrections. Our Technical Services group merely provides a service by mail, phone and with an extremely complex high-speed calculating machine. As far as the forester is concerned the difference between his desk calculator and us is in the distance to a machine and in the complexity of the calculator's capabilities.

Forest Management Decision Systems and Models

In going up the forest management avenue we can portray how our foresters tie into our systems and models by a picture such as Figure 2. We find YOU (the forester) at the bottom and FOG (Forest Operations Guide) at the top (rather apropos don't you think!). Seriously, the man's knowledge, experience and his ability to collect data plus the historical accounting facts provide the base of information which is summarized into FMIS (Forest Management Information System). FMIS accepts sampling data from both circular and variable radius plots taken in the field. Details such as forest site, type, density, volume, stand locations, logging conditions, cultural prescriptions and priorities find themselves in a databank stored on a magnetic disk pack which can be accessed by our computer programs.

The base information plus growth equations, yield tables and alternative harvesting time schedules can be included selectively in a mathematical programming model called FOG (Forest Operations Guide). I will admit there have been times when our solutions have been in the fog because we used weak data but for the most part we got a dehumidified answer when we ran a problem. Figure 3 is an attempt to show schematically a FOG problem.

FIGURE 2

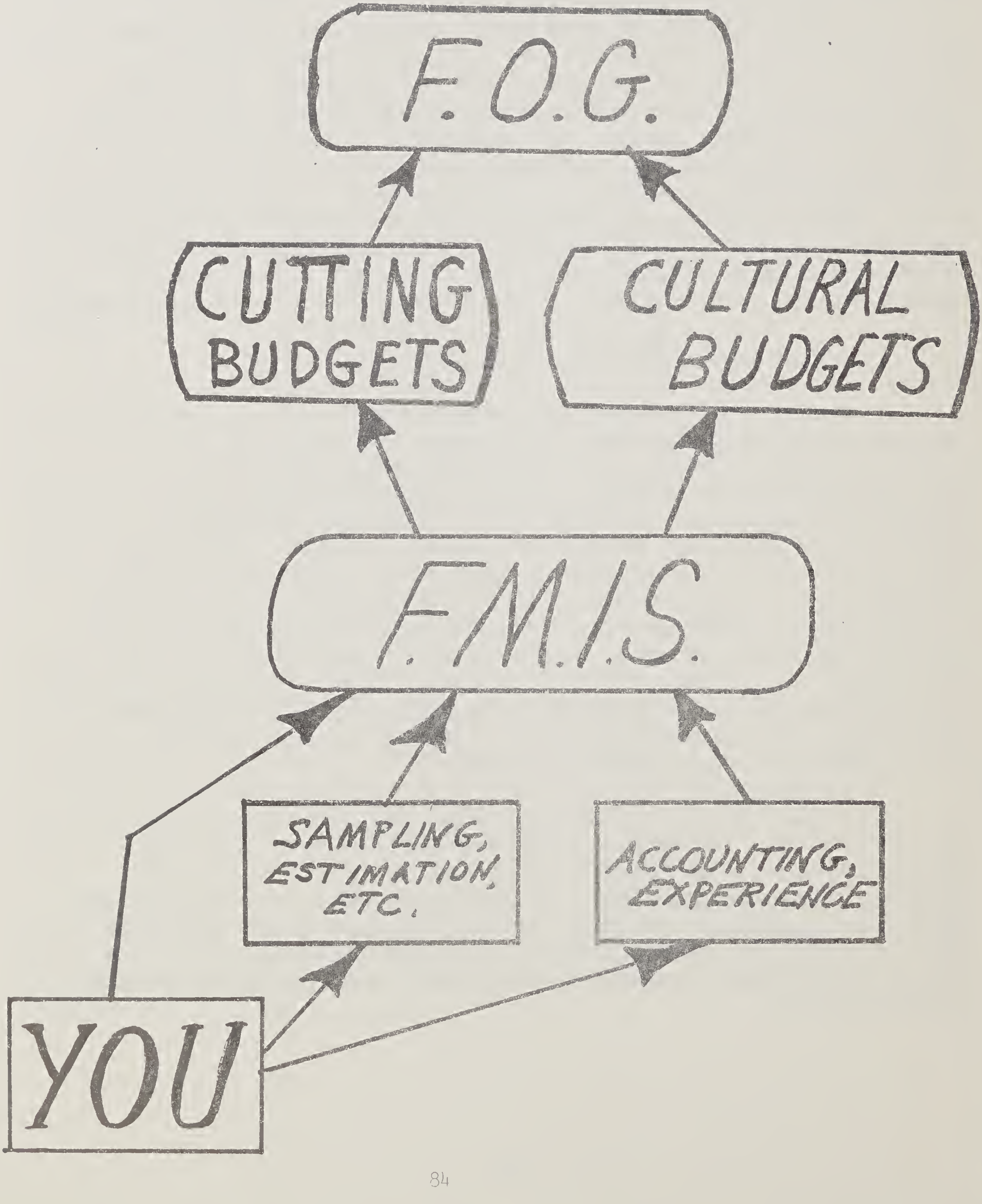
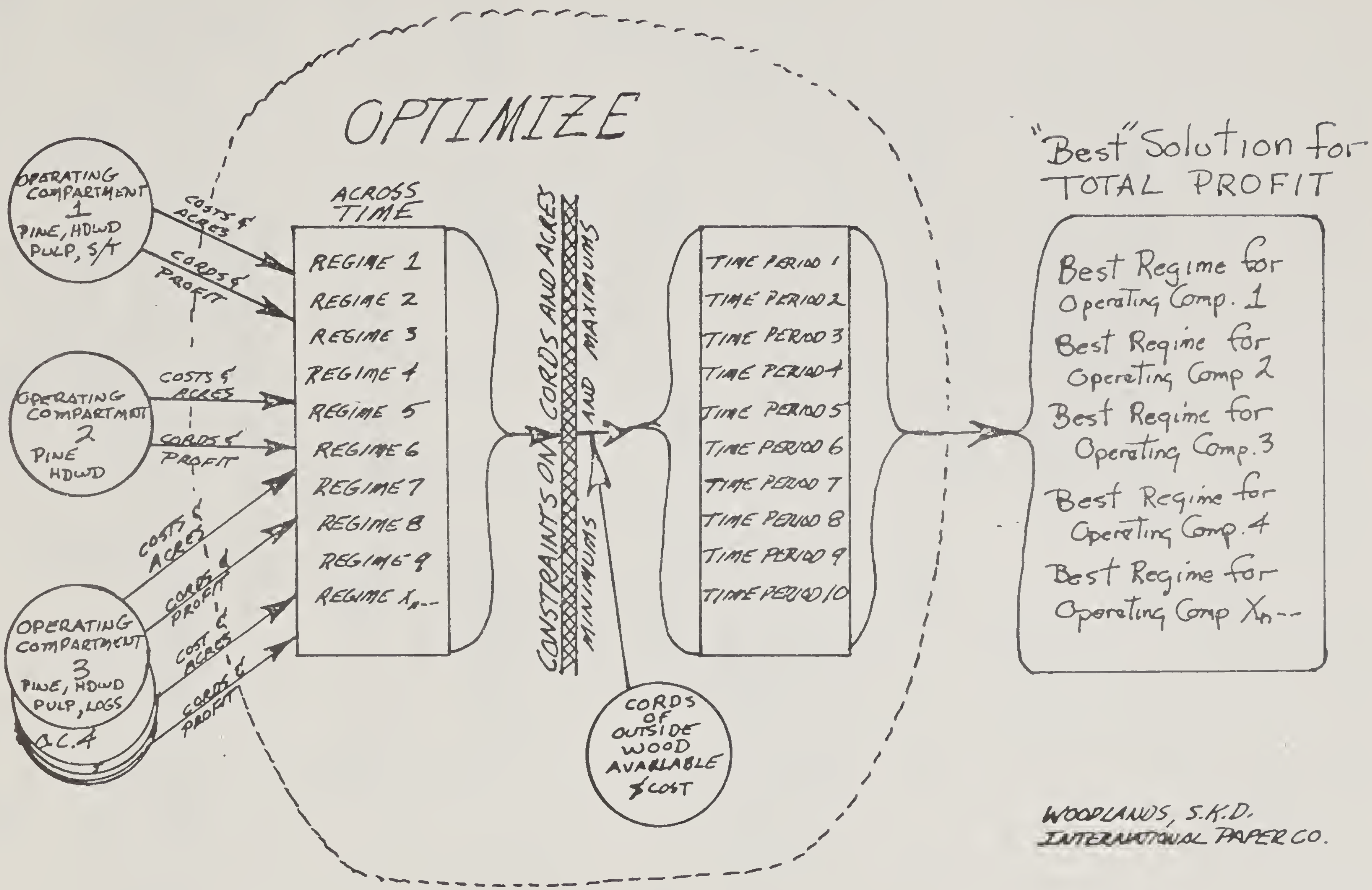

F.O.G.
CUTTING BUDGETS
CULTURAL BUDGETS
F.M.I.S.
SAMPLING, ESTIMATION, ETC.
ACCOUNTING, EXPERIENCE
YOU

FIGURE 3

SCHEMATIC OF F.O.G. (FOREST OPERATIONS GUIDE)



WOODLANDS, S.K.D.
INTERNATIONAL PAPER CO.

Our FOG model is a revised, revamped University of Georgia FOPS system stepchild. We were one of the original participants in the cooperative venture led by the University to optimize a harvesting pine pulpwood schedule. Our FOG includes pine sawtimber, hardwood pulpwood and sawtimber, our own growth predictions, yield tables instead of equations and a third generation mathematical programming problem formulation using ranging in the solution. We are not fully operational as yet. We have run about two-fifths of our lands one time through FOG to provide some interesting ideas on harvest schedules.

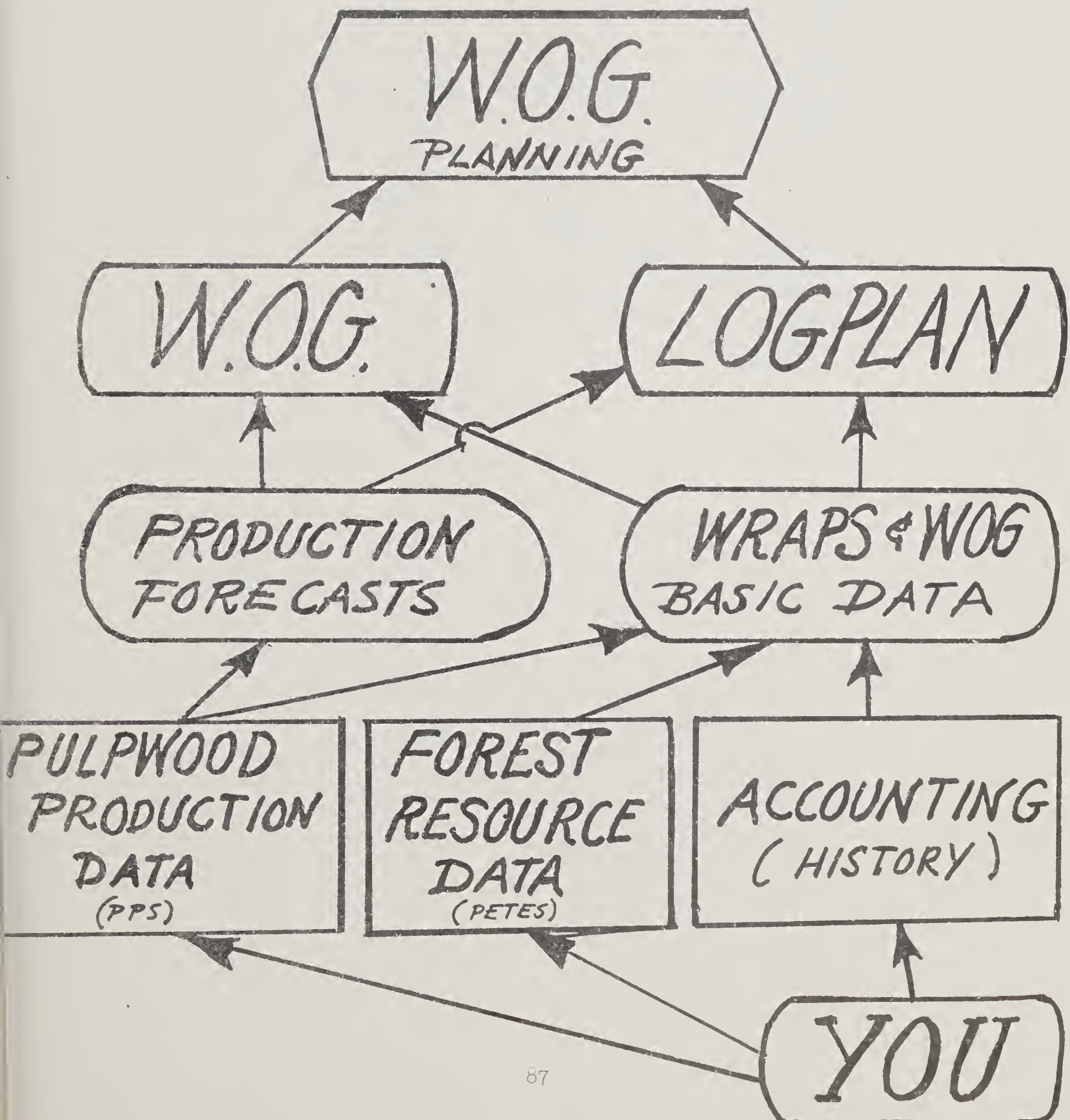
Our foresters realize that the last word in FOG is "Guide". The model cannot include all facets of the real world; and, as such, FOG provides only help for them in deciding which forests should be harvested first. An example of FOG not describing the real world lies with our Policy 11, mentioned on Monday by Mr. Nonnemacher, which states quite simply that no more than 500 contiguous acres can be clear cut in any one year. FOG does not care if two side by side blocks of land exceeding 500 acres are clear cut in one year; therefore our foresters must take a FOG solution and modify it by using profit margins to meet the requirements of Policy 11.

Wood Procurement Decision Systems and Models

Now, let's leave the forest management avenue and tackle wood procurement. Figure 4 shows the steps from the bottom YOU (the forester again provides the base data) and WOG (Wood Order Guide).

The forester collects the pulpwood production data which gives him and upper management trend knowledge (using a system called PPS to summarize and analyze pertinent facts) about logging systems and production rates. The wood accounting system (recently updated) provides the historical cost basis

FIGURE 4


W.O.G.
PLANNING
W.O.G.
LOGPLAN
PRODUCTION
FORECASTS
WRAPS & WOG
BASIC DATA
PULPWOOD
PRODUCTION
DATA
(PPS)
FOREST
RESOURCE
DATA
(PETES)
ACCOUNTING
(HISTORY)
YOU

for wood procurement yard costs, freight payments, labor charges, etc. We have a model which uses the U. S. Forest Service state inventory data, drain information and growth rates to keep current resource information on hand for each county in the South. We call this system "South wide Inventory Growth and Drain" - nicknamed "ETES" for Pete Chestnolvick who did it by hand for almost twenty years until four years ago when it was put on the computer. We use "PETES" to make forest resource studies for mill locations, timber trends and special surveys.

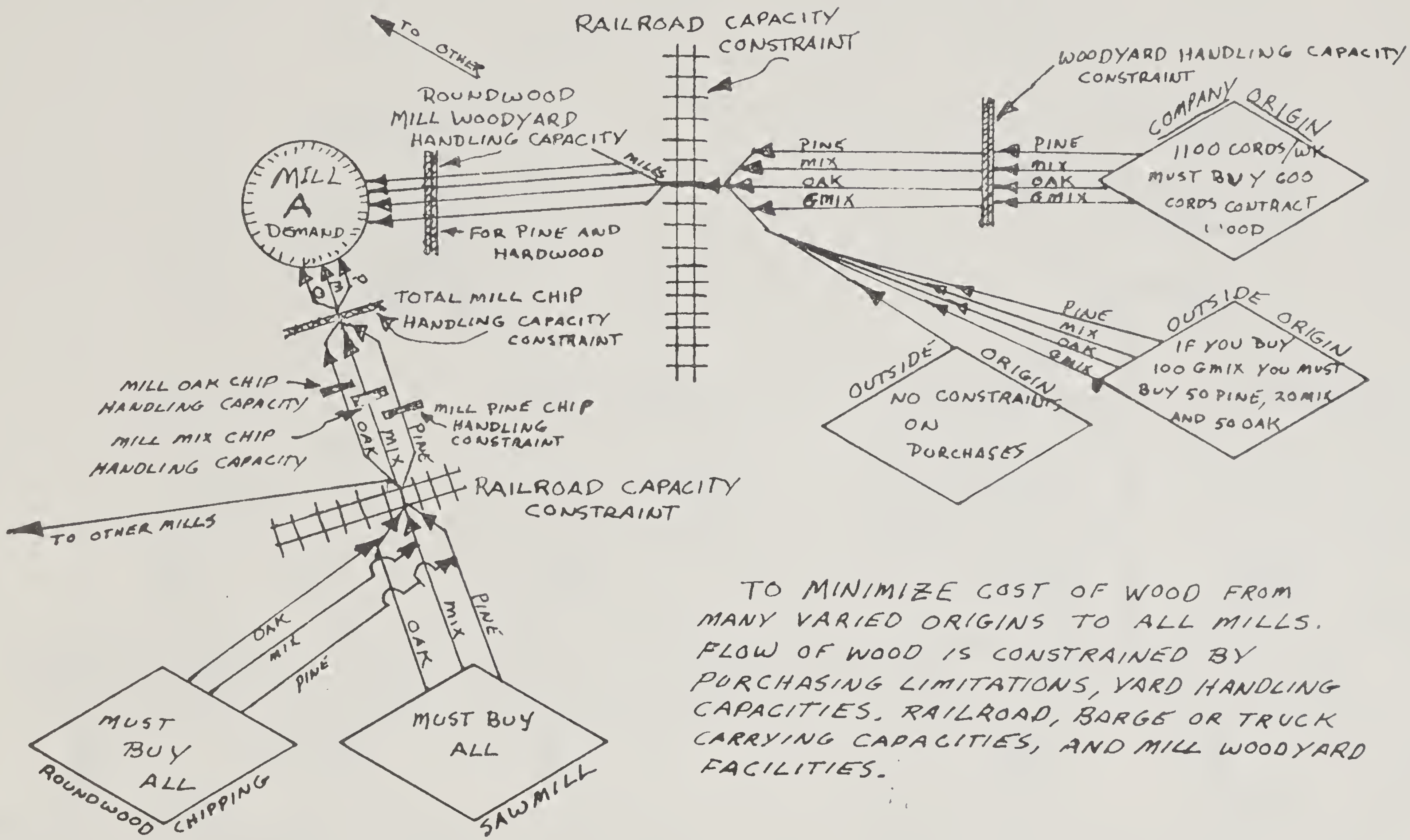
"PETES", PPS, and Wood Accounting develop information for the WRAPS (Wood Resource and Planning System) and WOG (Wood Order Guide) databank which is stored on a magnetic disk pack. Information for over six hundred origins of wood can be pulled out very quickly in many forms. The data includes estimates of wood which could be available to International Paper in the general vicinity of the origin, wood prices, mill destinations and transportation costs, yard capacities and costs, transportation load sizes, company wood quantitites and producing costs, plus other knowledge about the origin.

With forecasts of wood production capability of the contractors around the origin plus the data in the databank we have the input for WOG and a logging plan. WOG is a model of our wood procurement business. Basically, it follows the logic of a wood procurement forester as he determines the capabilities of his operating territory. WOG then goes one step farther and finds the lowest cost for logging all of our mills from all of our origins of wood across the South.

Figure 5 portrays a portion of a WOG problem. You can see in the sketch some of the constraints and capabilities of the model. We use the linear programming feature of a mathematical programming system to solve for lowest cost wood to the mills. The answer has no respect for administrative boundaries and will move wood from one place to another where necessary to obtain the lowest total cost. We found we could buy wood in Oklahoma for our Panama City, Florida

FIGURE 5

SCHEMATIC OF A PORTION OF A WOG TYPE PROBLEM



TO MINIMIZE COST OF WOOD FROM MANY VARIED ORIGINS TO ALL MILLS. FLOW OF WOOD IS CONSTRAINED BY PURCHASING LIMITATIONS, YARD HANDLING CAPACITIES. RAILROAD, BARGE OR TRUCK CARRYING CAPACITIES, AND MILL WOODYARD FACILITIES.

mill for less cost than buying wood in the upper portion of Georgia. The solution bought Oklahoma wood for our Springhill, Louisiana mill and then "bumped" wood across the middle south until wood east of Mobile was diverted to Panama City. The net cost was 15 cents a cord versus $2.50 a cord more from upper Georgia sources.

WOG (Plan) is a model used for estimating wood costs for mill expansions and new mills. WIG (Plan) uses the databank plus existing and potential origins of wood.

Towards and Optimum Planning System

We have reached the tops of both of our avenues and now we need to put them together, as shown in Figure 6. FOG and WOG provide information for a model named OPPLAN (Optimum Planning System) which uses a linear programming technique known as Generalized Upper Bounding to solve the necessarily huge problem which results when wood procurement and forest management are combined. The techniques can solve certain types of problems with as many as 20,000 quasi-equations in them. OPPLAN is not yet operational; although we have bench-marked a small test problem. In Figure 7, we see a sketch of a portion of the problem. The size of a problem can be understood when you realize that each possible species group product class origin time period has an equation for each destination. Thus, Pine Poles in O.C. 1 to pole plant 1 is one equation; Pine Poles in O.C. 1 to sawmill 1 is equation 2; Pine Poles to veneer mill 1 makes equation 3; and so on. When you finally develop equations for all products, by species, from all operating compartments to all possible destinations, you have one massive problem to solve for highest profits. And the raw data comes from foresters. You can now see why we emphasize the value of YOU in our systems.

We have other models in use - some in heavy use. For example, our Cash X analyzes long-term forest investments to show cash flow, profit, present worth, rate of return,

FIGURE 6

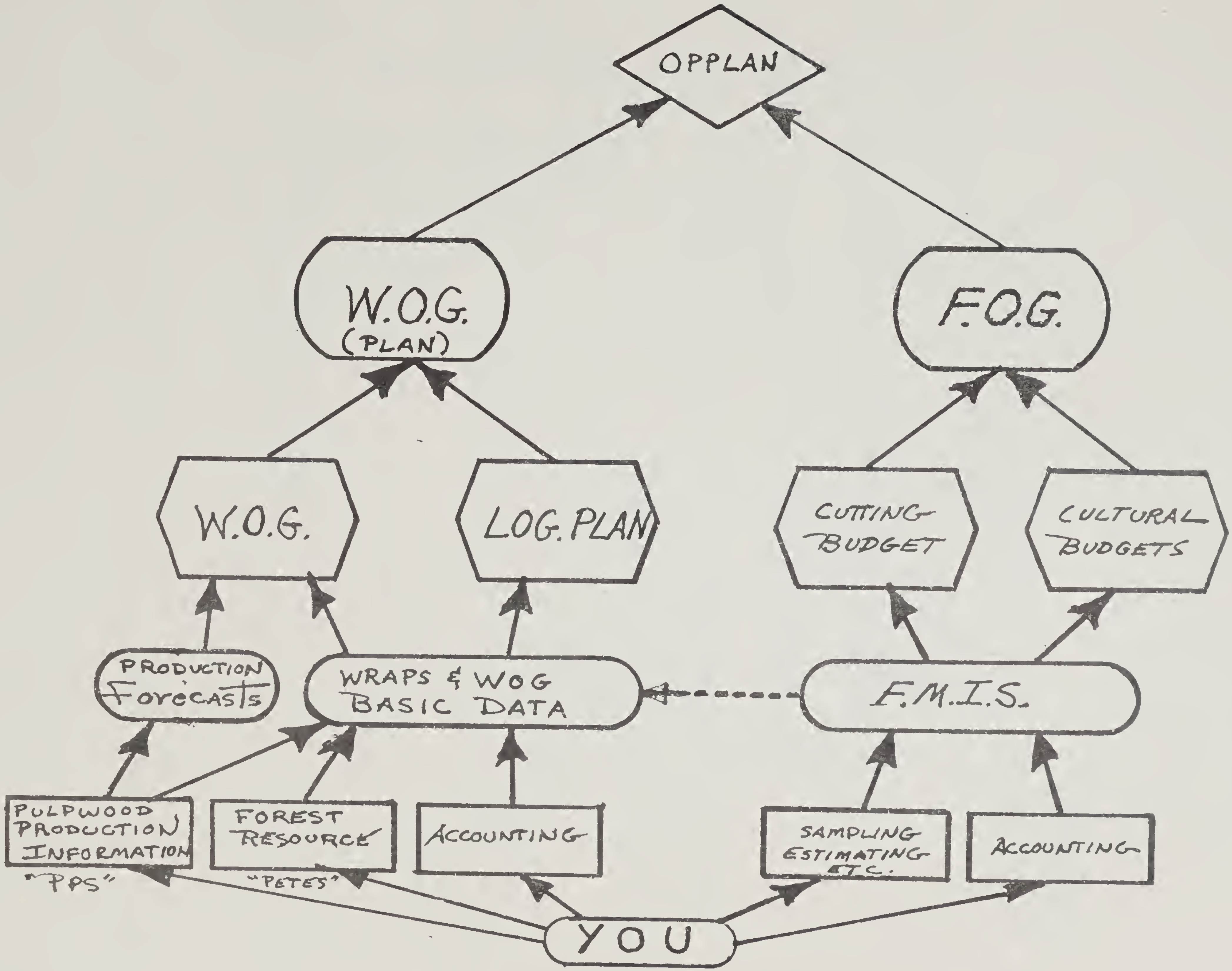
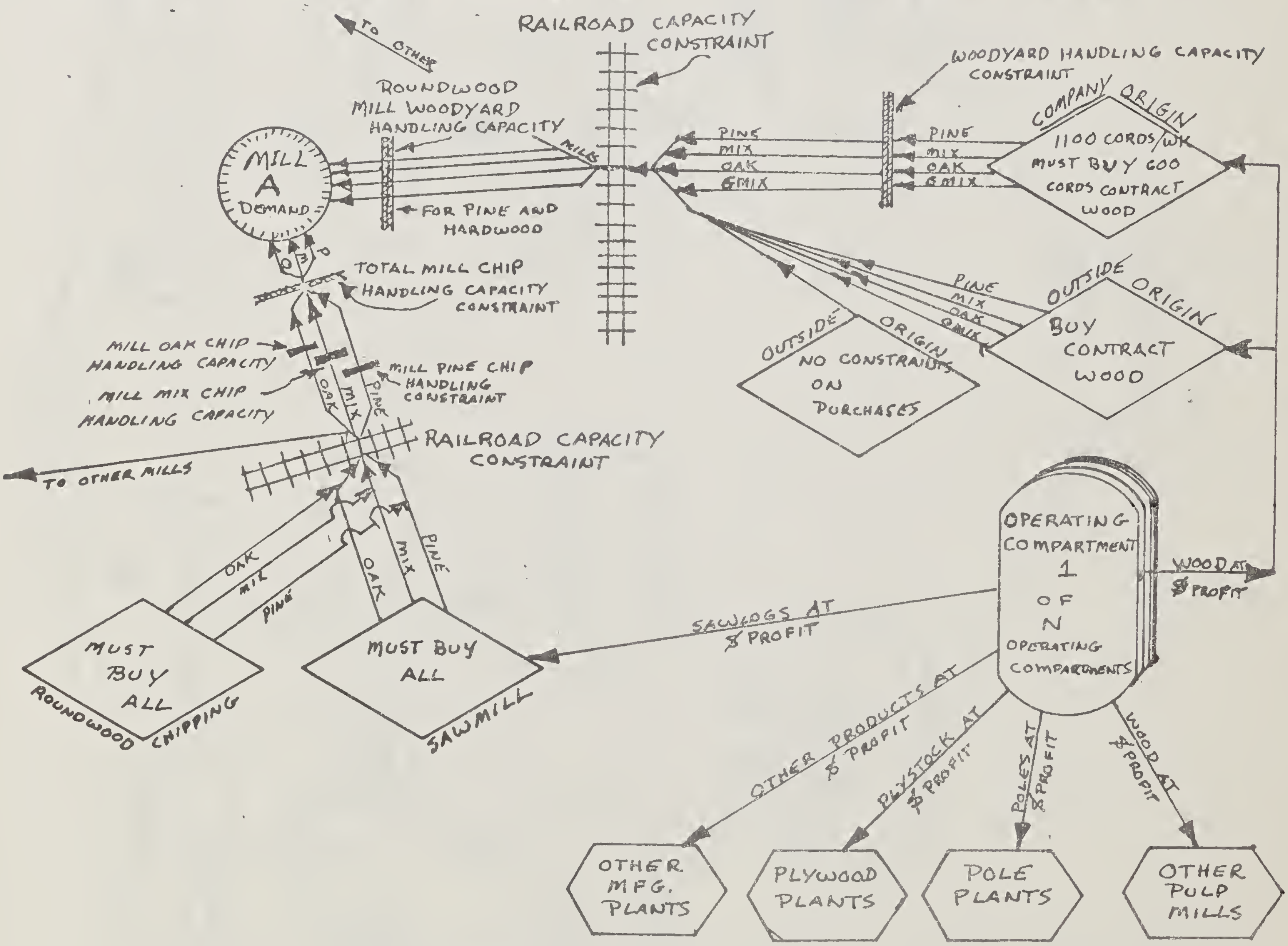

OPPLAN
W.O.G. (PLAN)
F.O.G.
W.O.G.
LOG. PLAN
CUTTING BUDGET
CULTURAL BUDGETS
PRODUCTION Forecasts
WRAPS & WOG BASIC DATA
F.M.I.S.
PULPWOOD PRODUCTION INFORMATION
"PPS"
FOREST RESOURCE
"PETES"
ACCOUNTING
SAMPLING ESTIMATING ETC.
ACCOUNTING
YOU

FIGURE 7

SCHEMATIC FOR OPPLAN TYPE PROBLEM (A PORTION)



discounted payback and other measures of economic worth. We now use a large scale financial model to study the possible effects on profit per share of common stock of accelerating forest growth rates, values, or costs. Risk Analysis provides a handy tool for evaluating equipment purchases and operations. This permits us to use ranges of values and the probabilities of occurrence within the ranges to forecast costs and DCFROI's. The data used in the models comes from the field.

We have also done some playing with yield equations in computer programs to get a "feel" for theoretical optimum rotation lengths based on various densities, logging costs, cultural costs and values.

We have on hand the simulation models of the American Pulpwood Association, Phase III, Harvesting Analytical Technique. We can run one of Tom Busch's TH-100's or a Buschcombine through the woods in the computer.

If someone had said to us twenty years ago as we were sloshing through some pocosin in North Carolina that we sould be running equipment through the same place except the place would be in core on a computer, we would have left that someone deep in that pocosin. The workings of the minds of foresters tied in with the calculating power of today's computer can solve any problem that might come along! Why, we are even dreaming of the next step after OPPLAN. Call it FANPLAN for FArout - Nearer than you think - PLAN (Figure 8).

Since most of our input data comes from our people, let us go back to the first illustration and add the decision-making steps which lead to the ballon, which, in turn, keeps the whole system going (Figure 9). The YOU man at the bottom ties it all together by providing the raw information and the mind to use the results of the models and systems to make better decisions.

Our Woodlands team has and will continue to make progress in all areas through the use of foresters, systems and machines.

CONCEPTUAL MODEL - MILLS AND WOODLANDS OPTIMIZE PROFIT

FIGURE 8

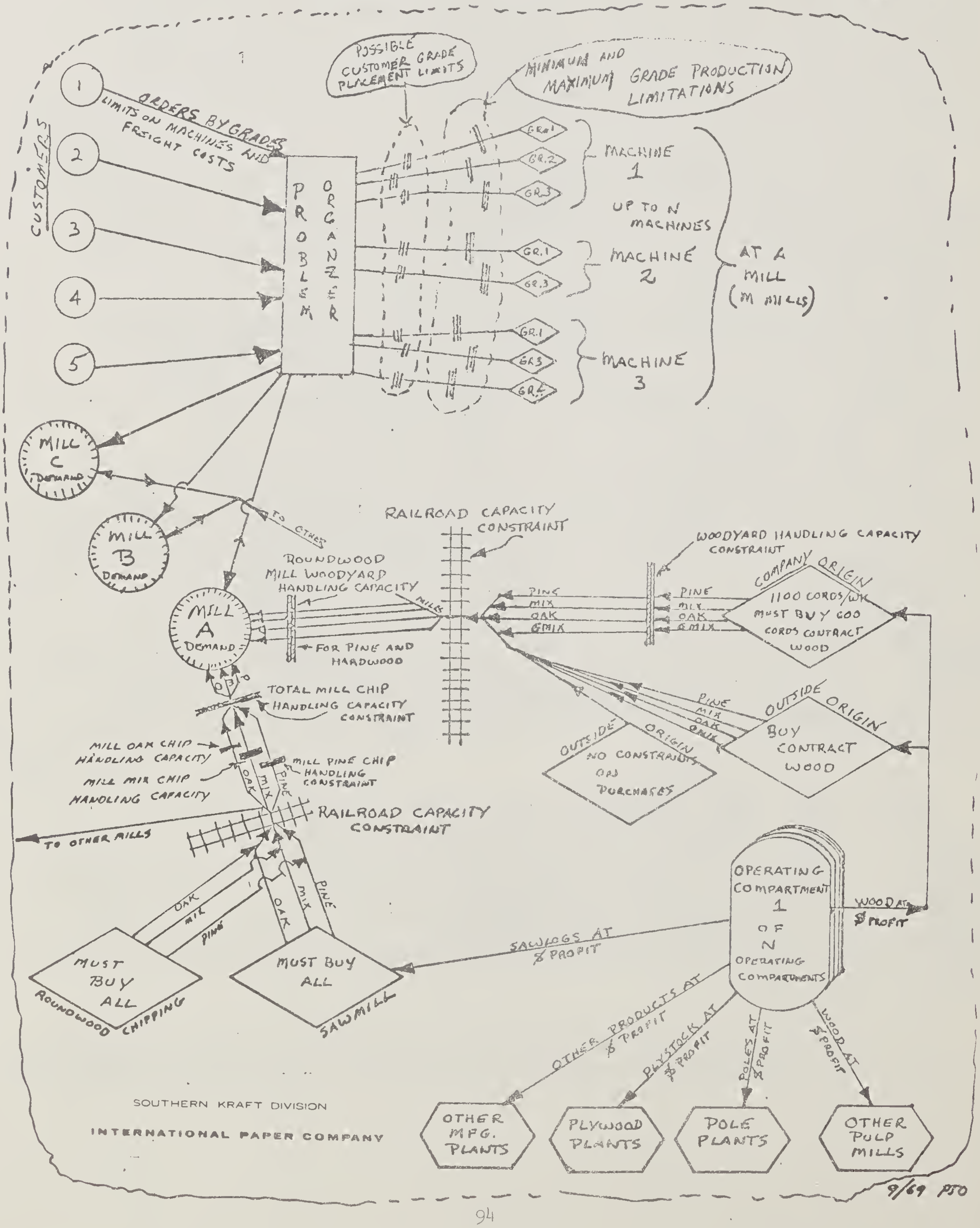
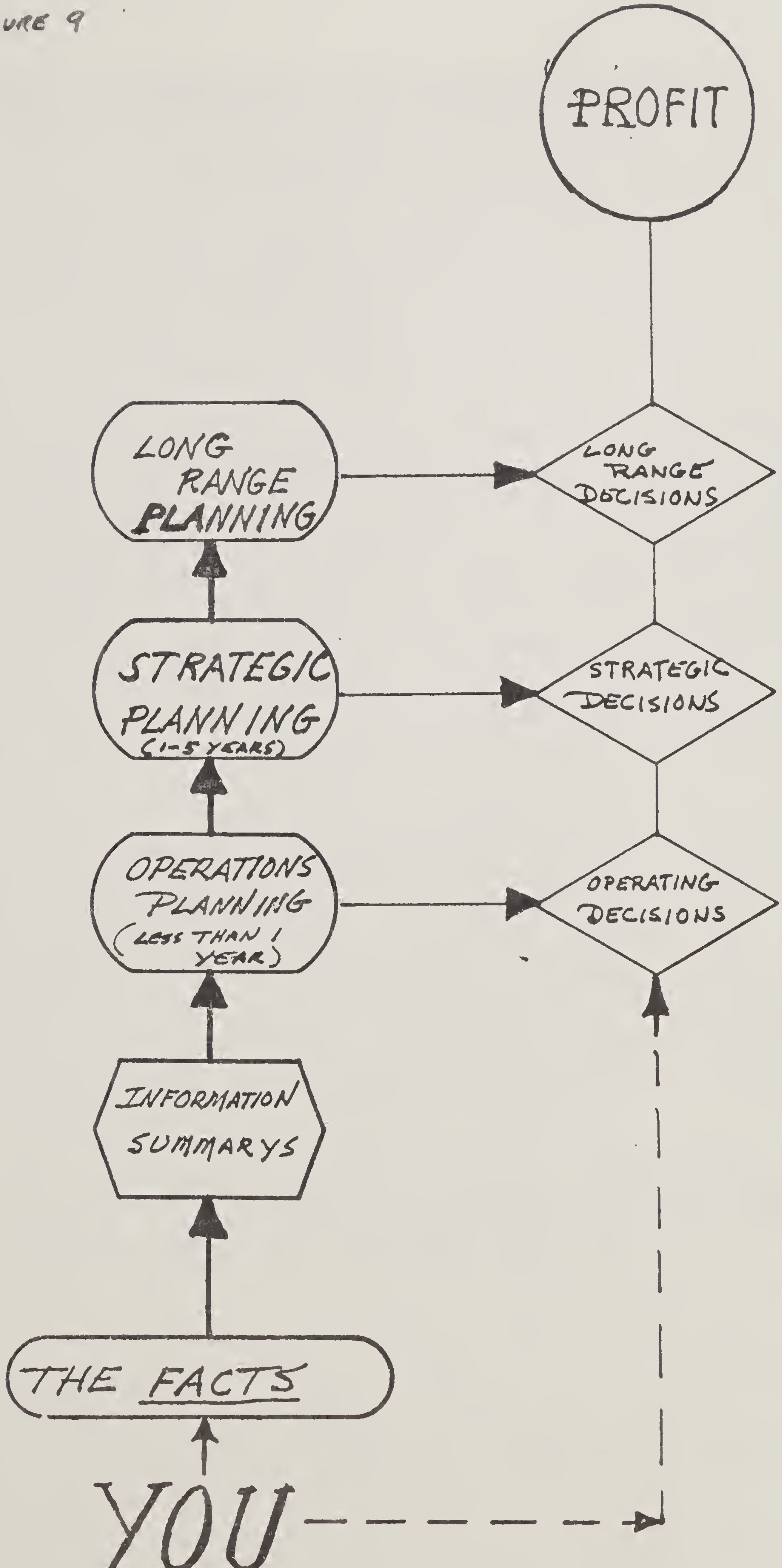


FIGURE 9


PROFIT
LONG RANGE PLANNING
LONG RANGE DECISIONS
STRATEGIC PLANNING (1-5 YEARS)
STRATEGIC DECISIONS
OPERATIONS PLANNING (LESS THAN 1 YEAR)
OPERATING DECISIONS
INFORMATION SUMMARYS
THE FACTS
YOU

COMPUTERIZED FOREST RESOURCE MANAGEMENT GAMES: AN OVERVIEW AND ASSESSMENT

B. Bruce Bare
University of Washington

Introduction

The purpose of this paper is to discuss computerized management games and their use in teaching forest resources management. The discussion will key on two general themes. The first of these themes is the notion of using competitive simulation models (i.e., management games) to assist in teaching forest management. And, owing to the general purpose of this workshop, the second theme concerns the use of digital computers as they are used in implementing the games in a teaching environment. In order to adequately discuss the implications and ramifications associated with these two points I will first discuss the use of computerized management games and provide some necessary definitions and concepts of gaming. This will be followed by a review of some existing forest management games with special emphasis devoted to a description of the Purdue University Forest Management Game. Lastly will be a discussion of our experience with the Purdue Game in a senior level forest management course and some general comments concerning the place of gaming in the education of forest managers at both the undergraduate and graduate levels, and the continuing education level. These introductory comments should have made it clear that while I intend to discuss our experiences with the Purdue Forest Management Game, I also plan to extrapolate from these experiences to more general comments concerning the pros and cons of the gaming methodology itself. Obviously, however, these two topics are by no means mutually exclusive.

History, Definitions, and Concepts of Gaming

Simply stated, management games are competitive simulation models where several teams compete against each other in a simulated environment controlled by certain game rules. An alternative definition is that a management game is a case study with feedback and a time dimension added (Carson, 1967). As these two definitions imply, games provide dynamic environments allowing students to gain valuable experience in a shorter time than is possible in real world situations.

The origin of management games is normally traced back to the development of war games. Although the history and origin of war games are somewhat unclear, chess and similar board games are generally acknowledged as the forerunners of modern war gaming procedures. As war games evolved, actual maps were introduced to replace the earlier board war games (Cohen and Rhenman, 1961). Military war games were introduced into the British Army in 1872 and into the United States armed forces soon thereafter (Thomas, 1957). Both Japan and Germany made extensive use of war games in the Twentieth Century (Jackson, 1959).

In addition to the development of war games, the recent availability of the digital computer and the development of the field of operations research also greatly influenced the development of management games. Greenlaw, Herron, and Rawdon (1962) point out that reasons for this were: (a) the operations research technique of simulation is intricately involved in the gaming approach, and (b) the operations research specialist was originally more competent than the educator in utilizing the facilities of a digital computer.

The American Management Association (in conjunction with the International Business Machines Corporation) developed the first management game in 1956 (Ricciardi, et al., 1957). Other early games originated with Andlinger (1958) and Schrieber (1958). The Carnegie Tech Management Game, developed during 1958-59, was probably the first really "complex" management game, requiring players to make over 300 decisions per period (Cohen, et al., 1964). Those interested in investigating any of the hundreds of games developed during the 1960's may refer to one of the bibliographies prepared by Greenlaw,

Herron and Rawdon (1962), Cohen and Rhenman (1961), Kibbee, Craft and Nanus (1961), IBM (1966), Hartmann (1966), Sord (no date), Naylor (1968), Graham and Gray (1969), Johnson (1969), Tannsey and Unwin (1969), Twelker (1969), Werner and Werner (1969), or Zuckerman and Horn (1970).

To conclude this introductory material I would like to briefly review the pros and cons of management gaming along with some of the more general concepts of gaming. The literature abounds with articles explaining the tremendous popularity of management games. Kibbee, Craft and Nanus (1961), believe that two unique characteristics which enable games to contribute so powerfully to management education are: (a) the novel use of the time dimension, and (b) the objectivity of the feedback. The use of a computerized simulation model permits one to compress the time horizon, permitting students to view the effects of their earlier decisions over an extended period of time.

The incorporation of the gaming concept into the instructional process creates a dynamic teaching environment which subsequently enables the student to make decisions and to test their effects on the simulated management environment. Further, as Cohen and Rhenman (1961) state, "the simulation of the environment to make possible feedback of the results of their actions to the players is the fundamental game idea...".

Another important feature of management games which undoubtedly has increased their effectiveness is the high degree of involvement and motivation students exhibit when playing a game. This motivation often puts students in a state of mind where they become more receptive to new ideas and new techniques. Further, games encourage students to utilize some of the quantitatively-oriented decision-making techniques learned in other courses, but perhaps never applied to a "real-life" problem.

Another reason often mentioned for using games is that they vividly point out the need for team organization, control and communication (Fulmer, 1963). Other reasons, as listed by Calvert (1971), are that games bring students into contact with a computer, illustrate the importance of considering uncertainty in the decision-making process, illustrate the importance of obtaining relevant and timely information, and provide students with an opportunity for effective intergroup learning with peers.

Although the overall concensus of many articles and books that I have reviewed indicates that management games have a place in the classroom and that they can be used as effective teaching devices, this does not infer that other educational methods are invalid or of lower value. In fact, there are numerous limitations often associated with the use of management games. Among these are: (a) high cost of instruction, (b) extensive development time, (c) problem of interpersonal rivalries which may develop due to intensive involvement, (d) high level of abstraction, (e) tendency to overemphasize quantitative factors in lieu of qualitative factors, (f) danger of transferring game results to real life situations, and (g) possibility of teaching erroneous concepts, facts or relationships that may have been incorporated in the model in a somewhat arbitrary fashion. Perhaps one of the most common criticisms of games often cited is that little empirical evidence exists that games do, in fact, teach whatever they are intended to teach. However, there has been a dearth of successful objective validation studies for evaluating the effectiveness of other teaching methods (i.e., lectures, case studies, and laboratories) as well. Speaking to this point, Calvert (1971) states "while it is true that the positive aspects of management games have yet to be shown in objective research or at least in regard to being a better or equal method of teaching compared to the use of other educational techniques, a crucial point that is many times overlooked is the fact that a game administrator, usually the class instructor, is on the scene...he has the responsibility for explaining the game model limitations and biases and preventing the erroneous or too literal transfer of game results to real life business situations." Many educators, sociologists and behavioral scientists are attempting to evaluate the educational value of management games. Those interested may consult a recent book entitled "Simulation Games in Learning" (1968) or consult the journal entitled Simulation and Games: An International Journal of Theory, Design and Research. Both sources are devoted to gaming and the evaluation thereof.

Management games normally fall into one of two general classes: total enterprise games which emphasize decision-making at a top executive level where management of the total firm is the objective, and functional games which emphasize lower or middle management in one particular area of a firm. Thus, instead of making decisions which affect the entire firm, students are limited to making detailed decisions affecting only one functional area of the firm. Most forest management games, including the Purdue University Forest Management Game, fall into this latter class.

Many other characteristics are often used to classify management games. Among these are: (a) manual versus computer models, (b) the number of players per team and the number of teams per game, (c) the length of the planning period, (d) single versus multi-product models, and (e) the orientation of the game for educational versus research objectives. This last point is quite important, for if the basic motive for constructing a management game is for educational purposes then the appearance of reality to the players may be more important than the realism of the model. As stated by Kibbee, Craft, and Nanus (1961), "the degree of reality needed in the model depends on the training objectives." Similarly, the distinction between verisimilitude and reality is related to the intended difficulty of the game as well as to the objectives of the game. Therefore, it is necessary to consider the purpose, the trade-off between verisimilitude versus reality, and the expected level of difficulty when developing or evaluating the potential of any particular management game.

Before closing this somewhat extended section on the concepts of gaming, I would like to mention four different ways management games can be used. These four ways, after Graham and Gray (1969), are:

1. Teaching specific items such as the importance of planned and critically timed decisions or the use of a particular technique such as linear programming or PERT.

2. Teaching general behavioral factors such as the importance of organization, control, communication, or matching tasks with people.

3. Teaching the power of modeling and the advantages of adopting a scientific approach to decision-making.

4. Generating a high degree of involvement where students can integrate specialized functions that they have learned in other classes.

Obviously, the items in this list are not mutually exclusive--a well structured game may succeed in all of the areas.

Forest Management Games

In the preceding section I have presented some of the pros and cons of gaming and some of the basic characteristics and concepts of gaming. Now, I would like to specifically discuss forest management games with special reference to the Purdue University Forest Management Game. Although a discussion of all available forestry-oriented management games is beyond the scope of this paper, I would like to list some of them and give a short description of each.

1) The Virginia Tech Industrial Forestry Simulator and Management Game. This game places the student in the position of a woodlands manager where he must make decisions concerning both wood procurement activities and forest management activities on company owned land. Given estimated budget levels for each of the next n years, the student makes his decision, runs the game for n years, and receives his output. If he satisfies mill requirements with no budget deficits he "wins". This program, written in Fortran IV for the IBM 360/65, is available to interested users. (Thompson and Simpson)

2) Pulpwood Procurement Simulator. This game, concentrating on wood procurement activities, charges each team with producing an adequate wood supply of a suitable species composition for the pulpmill to which it has been assigned. Since the wood is assumed to be harvested by independent suppliers, each team must make suitable contracts with these suppliers in order to insure a continuous wood supply. To accomplish this latter objective, each team must usually set up a quota contract network whereby certain suppliers contract to deliver a certain volume of wood at a set price. The game is programmed in Fortran IV for the IBM 360/67. (Borden, 1970; Chambers and Borden, 1969)

3) The Dynamic Forest Products Management Simulator. This game places the student in charge of a forest products firm which makes two plywood products. The producers acquire logs by making oral bids for public timber. Upon converting the logs into veneer and subsequently into the two plywood products, the producers sell the material to wholesalers. The wholesalers in turn market the plywood products in different sales regions. Student teams may experiment with different inventory rules, manufacturing processes and marketing and pricing strategies. The game is programmed in Fortran IV for the IBM 360/50. (Ramsing, 1970)

4) The Harvard University Forest Simulator. This well known simulator allows students to manage a forest property for timber production under various operating and economic conditions. This simulator is written in Fortran IV for several computers. (Gould and O'Regan, 1965; O'Regan, 1965; O'Regan, Arvanitis and Gould, 1965; Walton, 1965; Howard, Gould and O'Regan, 1966; Gould, 1967)

Other forestry-oriented management games include a fairly simple game designed to simulate the random occurrences of forest fires in large areas and the effects that the allocation of certain types of available resources will have on the fires[1/]. In addition, the U. S. Forest Service is developing a multiple-use gaming model which will be used at the forest level. The model entitled SNAFOR (Simulated National Forest Region) is an outgrowth of the earlier Land Classification and Land Management Game (LACLAG) also developed by the U. S. Forest Service (Row and Schmelling, 1971; Hull). The basic objective of both models is to simulate a total national forest management situation including regional, ecologic, social, economic, and political interactions[2/]. Others developing games include Peter Dress, School of Forest Resources, Pennsylvania State University--a recreation site development game, and William Pierce, School of Forestry, University of Montana--a timber management game. In addition, Walters and Bunnell (1971) and Giles and Lobdell have developed wildlife management games.

1/ Personal communication with William Bentley, School of Natural Resources, University of Michigan, Ann Arbor, Michigan.

2/ Personal communication with Dick Hull, Eastern Region, U. S. Forest Service, Milwaukee, Wisconsin.

Lastly, I would like to mention the gaming activities at the Center for Quantitative Science, University of Washington. During the summer of 1970 the Ford Foundation sponsored an interdisciplinary workshop on resource management games. Under the overall guidance of Gerald Paulik, fifteen modelers came to the campus and worked on various types of management games dealing with forestry, fisheries, ecology, water and wildlife. The ensuing package of programs has been tested at Florida State University, the University of Michigan and the University of Washington. Those interested in this package of teaching games may contact either Paulik or myself.

Purdue University Forest Management Game

So far this afternoon I have attempted to introduce the subject of management games and I have briefly reviewed some of the available forestry games. Now I would like to discuss our use of the Purdue University Forest Management Game. The original version of the Purdue University Forest Management Game was developed during 1967-69 under the guidance of Otis Hall. Since then, the game has undergone several revisions and, in addition, a second simulation model called The Forest Management Simulator has been developed to supplement the original gaming model. These two models now constitute the total package. Although I don't intend to spend a great deal of time describing the details of either model I will briefly outline the basic structure of the gaming package.

The purpose of the Purdue University Forest Management Game is to simulate the operations of an industrial forest property so that forest management students may observe how the various biological and financial factors associated with operational forest management interact to affect the behavior of the forest system. The game concentrates on the preparation of an annual budget of expenditures and an annual schedule of management activities. Thus, it emphasizes operational or middle management activities more strongly than policy formulation and long-range planning (Bare, 1970a)

The Forest Management Simulator is designed to counter this orientation and to instill an appreciation for the long-term consequences of alternative management strategies. Since the determination of long-term goals, objectives and consequences of alternative management strategies must be evaluated prior to their implementation on a short-term basis, the Forest Management Simulator necessarily is used prior to the management game itself. (Bare, 1970b)

Given the pulpmill's annual requirements for roundwood and the expected annual budget, each team sets out to determine how it will manage its forest district. Using the Forest Management Simulator, teams are able to evaluate the consequences of decisions relating to regeneration and site preparation, thinning, regeneration delays, methods used to compute the allowable cut, methods used to allocate the allowable cut to specific compartments, and the interval between updates of the allowable cut. Using a predetermined discount rate the simulator generates the net present worth of all cash inflows and outflows during each simulation run. After extensive experimentation with the simulator teams select that strategy which will: (a) generate a satisfactory cash flow stream, (b) satisfy the requirements of the pulpmill, and (c) produce a forest capable of sustaining production at the desired level. Lastly, to be feasible it must be possible to implement any selected strategy within the expected budget.

Following experimentation with the long-term simulator the student teams play the management game and attempt to implement their strategies on a year to year basis. Since operating funds are allocated as a function of the previous years' performance, teams are generally unable to implement their strategies as originally planned. As time progresses the discrepancy between long-range plans and annual plans normally becomes increasingly greater. Therefore, after simulating a period of five years, each team is given an opportunity to alter its long-term management strategy. The Forest Management Simulator is used in developing this new management strategy just as it was for the original strategy. I should also add that the game moderator uses the Forest Management Simulator to determine the annual allowable cut for each district based upon the management strategy adopted for the particular district.

Experience with the Purdue University Forest Management Game

I now want to present some personal views concerning the use of computerized management games based upon my experiences with the Purdue gaming package. For the past three years I have used the Purdue Forest Management Game in a senior level forest management course. Although the Forest Management Simulator has only been used during the past two years, there is little question in my mind that the addition of this simulator greatly improves the total gaming experience.

First, I feel that exposure to computerized simulation models has been a very beneficial consequence of the gaming exercise. To date the game has been implemented on batch, remote batch and time-sharing computer systems. However, due to the number of decisions required during each year of simulated play and the forethought required prior to making decisions for any particular year, the game may be better implemented on a batch or remote batch system than on a time-sharing system. It seems to me that games best suited for time-sharing systems are those where only one or two decisions requiring little study are necessary in order to play the game. Of course, the advantage of any time-sharing system is rapid turnaround time once the decisions are entered.

Second, students gain valuable experience in the total decision-making process. By this I mean the process of defining a set of goals and objectives, identifying a set of alternatives which if implemented will satisfy these goals, evaluating each alternative using some pre-determined criterion, selecting the most satisfactory alternative, and finally implementing the decision. I feel that exposure to this process in the context of a specific problem-solving situation is one of the most lasting and beneficial rewards that students receive from participating in the gaming exercise.

Third, I feel that exposure to a model which attempts to integrate knowledge learned in other courses, and stimulate application of this knowledge to a specific porblem is a valuable contribution of the gaming exercise.

Fourth, the act of playing the game seems to stimulate or motivate students much more than does a traditional lecture or case study course. Of course, all students are not motivated to the same degree. I think this is because we are using the computer. Since some students distrust or dislike computers, they tend to be "turned off" by the gaming exercise. The game also seems to stimulate the use of quantitative methods. I think this is due to the student's belief that since we are using computers only quantitative in formation is relevant. This implies to them that quantitative analysis is appropriate and hence they are stimulated to do so.

Lastly, the Purdue gaming exercise provides students with valuable experience in both preparing a long-term plan using modern simulation methods and in implementing the plan through the preparation of an annual budget and a compartment by compartment schedule of management activities. I don't yet know the impact of the gaming experience on the student's later professional job development and advancement but there is little doubt in my mind that the exercise does give the student an opportunity to apply his knowledge and talent within a decision-making context.

Concluding Remarks

This afternoon I have discussed the pros and cons of gaming, briefly reviewed some existing forest management games, described the Purdue University Forest Management Game, and related some of our experiences with the Purdue Game. Before concluding my talk I would like to say a few additional words about some potential uses of the Purdue Game and management games in general.

Most of the discussion concerning our use of the Purdue Game has centered around its use in a senior level forest management course. In using the game within this type of environment the emphasis has been on the use of the game and not on an evaluation of the model, how it is constructed, or how it operates internally. However, we plan to use the game within this latter context in our graduate level forest management course this year. Instead of playing the game per se, graduate students will investigate how the model is constructed, how it operates,

how embedded assumptions effect the behavior of the model, etc. We also plan to critically review several other existing simulators in an effort to assess the current state of the art of forest management simulation models.

Another type of user who could benefit from playing management games is the practicing forest manager. We have used the Purdue Game (not the Forest Management Simulator) in a continuing education short course where we placed more emphasis on a critical review and examination of the game than we did upon its actual use. However, the use of any management game in such a short course is dependent upon the objectives of the course and the background and experience of the course participants.

Hopefully, these concluding remarks have made it clear that to a large degree the objectives of any particular course and the previous experience of the course participants dictates the manner in which a particular management game is used.

Literature Cited

1. Andlinger, G. R. 1958. Business Games: Play One, Harvard Business Review 36(2):115-125.

2. Bare, B. 1970a. Purdue's Forest Management Game, Journal of Forestry 68(9):554-557.

3. Bare, B. 1970b. User's Manual for the Purdue University Forest Management Game, Center for Quantitative Science, University of Washington, Seattle, Wash. Mimeo. 72 pp.

4. Boocock, S. and E. O. Schild (Eds.). 1968. Simulation Games in Learning, Sage Publications, Inc. Beverly Hills, California.

5. Borden, Y. 1970. User's Manual for a Pulpwood Procurement Simulator, School of Forest Resources, Pennsylvania State University, State College, Penn. Mimeo.

6. Calvert, D. E. 1971. The Pros and Cons of Management Games, Presented at XVIII International Meeting of Institute of Management Sciences, Washington, D. C.

7. Carson, J. R. 1967. Business Games: A Technique for Teaching Decision Making, Management Accounting, October.

8. Chambers, P. and Y. Borden. 1969. A Pulpwood Procurement Simulation and Game, Research Briefs, 4:30-32, School of Forest Resources, Pennsylvania State University, State College.

9. Cohen, K. J. and E. Rhenman. 1961. The Role of Management Games in Education and Research, Management Science 7(2): 131-166.

10. ______________ et al. 1964. The Carnegie Tech Management Game, Irwin, Inc., Homewood, Illinois. 389 pp.

11. Fulmer, J. L. 1963. Business Simulation Games, Monograph C-12, South-Western Publishing Company, Cincinnati. 120 pp.

12. Giles, R. and C. Lobdell. No date. SCRAP - A Computer-Based Wildlife Management Game, Division of Forestry and Wildlife, Virginia Polytechnic Institute and State University, Blacksburg, Mimeo. 10 pp.

13. Graham, R. and C. Gray. 1969. Business Games Handbook, American Management Association, New York. 480 pp.

Gould, E. and W. O'Regan. 1965. Simulation - A Step Toward Better Forest Planning, Harvard Forest Paper No. 13, Petersham.

15. Gould, E. 1967. Simulation and Forestry, XIV International Union of Forestry Research Organizations, Sec. 25, p. 96-104, Munich.

16. Greenlaw, P. S., L. W. Herron, and R. H. Rawdon. 1962. Business Simulation in Industrial and University Education, Prentice-Hall, Inc., Englewood Cliffs. 356 pp.

17. Hartmann, J. 1966. Anotated Bibliography on Simulation in the Social Sciences, Rural Sociology Report No. 53, Iowa State University, Ames, Iowa.

18. Howard, R., E. Gould, and W. O'Regan. 1966. Simulation for Forest Planning, Simulation 7(1):44-52.

19. Hull, R. No date. User's Manual for the Land Classification and Land Management Game, Eastern Region, U. S. Forest Service, Milwaukee, Wisconsin. Mimeo.

20. International Business Machines. 1966. Bibliography on Simulation, 320-0924, White Plains.

21. Jackson, J. R. 1959. Learning from Experience in Business Decision Games, California Management Review 1(2):92-107.

22. Johnson, E. 1969. Simulation and Gaming in Business and Economics in the 1960's: A Bibliography, College of Business Administration, University of Iowa, 48 pp.

23. Kibbee, J. M., C. L. Craft, and B. Nanus. 1961. Management Games, Reinhold Publishing Corp., New York. 347 pp.

24. Naylor, T. H. 1968. Bibliography on Simulation and Gaming, TIMS College on Simulation and Gaming, Duke University, Durham.

25. O'Regan, W. 1965. A Simulation Approach to Timber Management, In Proceedings of Seminar on Operations Research in the Forest Products Industry, I.B.M., San Francisco, pp. 113-132.

26. O'Regan, W., L. Arvanitis, and E. Gould. 1965. Systems, Simulation, and Forest Management, In Proceedings of Society of American Foresters Annual Meeting, pp. 194-198.

27. Ramsing, K. 1970. Forest Industries Management Simulator, Forest Industries Management Center, College of Business Administration, University of Oregon, Eugene, Oregon. Mimeo.

28. Ricciardi, F. M., et al. 1957. Top Management Decision Simulation: The AMA Approach, E. Marting (Ed.), American Management Association, New York. 125 pp.

29. Row, C. and B. Schmelling. 1971. Resource Information Planning Systems: A Catalog of Computerized Systems in the U. S. Forest Service, Washington, D. C.

30. Schrieber, A. N. 1958. Gaming - A Way to Teach Business Decision-Making, University of Washington Business Review 17(7):18-29.

31. Sord, B. H. No date. Selected Bibliography of Business Game Simulation, College of Business Administration, University of Texas, Austin.

32. Tansey, P. and D. Unwin. 1969. Sources in Simulation and Academic Gaming: An Annotated Bibliography, British Journal of Educational Studies, 17(2):193-208.

33. Thomas, C. J. 1957. The Genesis and Practice of Operational Gaming, In Proceedings of the First International Conference on Operational Research, Operations Research Society of America, Baltimore. pp. 64-81.

34. Thompson, E. and M. Simpson. No date. Use of a Computer Simulation for Improved Forest Management Teaching, Division of Forestry and Wildlife, Virginia Polytechnic Institute and State University, Blacksburg, Mimeo, 7 pp.

35. Twelker, P. 1969. Instructional Simulation Systems: An Annotated Bibliography, Continuing Education Publications, Waldo Hall, Oregon State University, Corvallis, Oregon 286 pp.

36. Walters, C. and F. Bunnell. 1971. A Computer Management Game of Land Use in British Columbia, Journal of Wildlife Management, 35(4):644-657.

37. Walton, G. 1965. A Study to Develop a Forest Management Simulator, M. S. Thesis, Harvard Forest, Petersham.

38. Werner, R. and J. Werner. 1969. Bibliography of Simulations: Social Systems and Education. Western Behavioral Sciences Institute, 1150 Silverado, La Jolla, Calif., 178 pp.

39. Zuckerman, D. W. and R. E. Horn. 1970. The Guide to Simulation Games for Education and Training, Information Resources, Inc., 1675 Massachusetts Avenue, Cambridge, Mass.

Additional Selected References

1. Babb, E. and L. Eisgruber. 1966. Management Games for Teaching and Research, Educational Methods, Inc. Chicago.

2. Bare, B. 1971. Applications of Operations Research in Forest Management: A Survey, Quantitative Science Paper No. 26, Center for Quantitative Science, University of Washington, Seattle.

3. Northrop, G. M. 1967. Use of Multiple On-Line, Time Shared Computer Consoles in Simulation and Gaming, Rand Corporation, P. 3606.

4. Paulik, G. J. 1969. Computer Simulation Models for Fisheries Research, Management and Teaching. Transactions of American Fisheries Society 98(3):551-559.

5. Pualik, G. J. 1969. Digital Simulation Modeling in Resource Management and the Training of Applied Ecologists, Quantitative Science Paper No. 6, Center for Quantitative Science, University of Washington, Seattle.

6. Raser, J. 1969. Simulation and Society: An Exploration of Scientific Gaming, Allyn and Bacon, Boston. 180 pp.

7. Schultz, R. 1966. Game Simulation and Wildland Fire, Journal of Forestry 64(12):791-800.

8. Stoll, C. and M. Inbar (Eds.) 1969. Social Simulations, American Behavioral Scientist. 12(6). Entire issue devoted to simulation and gaming in social and behavioral sicences.

9. Tansey, P. and D. Unwin. 1969. Simulation and Gaming in Education, Barnes and Noble, New York.

ASPECTS OF THE DEVELOPMENT OF MANAGEMENT INFORMATION SYSTEMS IN AUSTRALIAN FORESTRY

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What is a Management Information System?

As the name implies, it is a system for the supply of information to management. But then so is the traditional manual filing system used in some form or another by all organizations. To discuss what is unique about a Management Information System (MIS), let us examine some of the problems faced by a manager in desiring to acquire some information.

First of all the manager frequently has no measure of the accuracy or reliability of the information that reaches him via a manual filing system. Often in its trek from the data source to him, the information is summarized, extracted, abridged or edited. Usually the manager has no time to trace it back to its source and so is forced to accept it at face value.

Nor, generally, does the manager have time to wait for information to be acquired. Usually a manager requests information because he has a decision to make and rarely can the decision be deferred. Furthermore, he usually wants the information to be based on the most up-to-date data available, and not to be incomplete because the latest data have not yet been processed.

It is essential that the information be complete with respect to the decision to be made. Incomplete information usually leads to inadequate decisions. At the same time the manager requires that the information be concise. It is obviously inefficient for managers to have to wade through files to find the desired information, yet this is frequently necessary.

Finally, it is essential that the information he acquires be relevant to the manager's requirements, to the problem to be solved, and to the decision to be made.

It is the aim of a Management Information System to meet all these requirements; i.e., to provide information that is accurate, timely, complete, concise and relevant (Sanders, 1970). We can thus consider the MIS as being not A system, but THE system for the supply of information to management.

The question is, is it an attainable goal? Is it possible to set up a system in an organization to provide every manager with such information on demand? Well, let it be admitted right now, probably not. But striving for the Holy Grail or the "impossible star" has often proved a fruitful activity for Mankind, and the search for "the elusive MIS" (Head, 1970) has had at least two important pay-offs.

Firstly, it has given an opportunity to view the organization as a single total system of information transfer--a new way of looking at the structure of an organization which has proven quite enlightening and often rewarding. Secondly, it has been shown that it is feasible to develop MIS's for sub-systems of the total system and to provide at least some managers with quality information.

Such is the aim and promise of the MIS. But what does an MIS look like? Let's consider some characteristics of these systems. Not all MIS's have all of these characteristics but together they form a fairly typical group.

The basis of all Management Information Systems if the "data base", equivalent to the files of a filing system. Into this data base flow all the data relevant to the organizational system, and the success of the MIS depends to a large extent on how well the data base is organized for data capture and retrieval. Because of the large size of this data base and the desirability of fast retrieval, it is inevitable that the data be stored in some computer-processable form, such as on magnetic tapes or discs.

A second feature is that the data is captured in as raw a form as possible; i.e., close to the source of data. This decreases the chance of human error and preserves the accuracy of the data.

Thirdly, there is frequently some means of keeping the base up to date, either by frequent up-dating, or by projecting the data into the future or a combination of both. This ensures the timeliness of the data.

Fourthly, in the typical MIS, reports are produced only when necessary. For the operations manager this may mean "exception reporting" with reports produced only when operations get out of control, for instance when unit costs exceed certain defined tolerances. For the planning manager this may mean "demand reporting" with a report produced only when he requests it.

Finally, many MIS's have provision for answering "what-if" type questions. The manager who wishes to know what would happen under certain hypothetical circumstances is able to find out by simulating the situation without incurring the cost of a real-world trial.

The mechanism for carrying out the Management Information System is the large-scale computer together with remote terminals so that data can be entered close to the source and so that the manager can interact with the System personally.

The introduction of a Management Information System into an organization is no minor event. It cannot be at all equated with the more common computer applications which generally amount to little more than the automation of certain clerical functions, such as payrolls, sales procedures and inventory analyses. Such applications while relieving the organization of much drudgery-type record-keeping will rarely be of great assistance to the manager in his decision-making role. The information that he gets from such systems will usually be more accurate than previously. He may get it sooner than before, but rarely will it provide him with fast access to the information that he wants (he may well be snowed by computer output), and rarely will it allow him to manipulate the data for projection or simulation analyses.

The development of a Management Information System can and indeed should strike at the very heart and soul of the organization. The builder of an MIS must determine the information needs of every manager in the system and thus he must have in very sharp focus the goals and aspirations of the total organization as well as of the individual managers. The determination of the organization's goals can be a difficult and painful process--it

is certainly not as simple as looking in the introduction of the latest annual report! The critical examination of the information needs of the organization's managers can be no less thankless, if not downright embarrassing.

At the same time the cost-effectiveness of an MIS is not nearly as apparent as say a payroll automation (Head, 1967). The benefits of the latter can be measured in terms of reduced clerical effort but the benefits of improved decision-making, like forest recreation, are not nearly so easy to quantify. It is not surprising therefore that organizations have been reticent to engage in the considerable expense and soul-searching necessary for the development of an MIS. In fact, it may well be that some organizations which have stable goals and growth patterns and thus whose managers have well-defined decision-making responsibilities, might not profit too much from such an experience.

However, in a dynamic society such an organization is the exception, and drastic changes in organizational goals and managerial responsibilities are occurring with increasing frequency. Such changes often create opportunities for structural changes within an organization as well as creating demands for types and quality of information not previously necessary. Such changes may well stimulate an interest in some form of MIS. It was in fact such a change which stimulated an interest in these systems in several forestry organizations in Australia.

Australian Experience with Forest MIS's

In 1967 the Softwood Forestry Agreements Act became law in the Commonwealth of Australia Parliament. This Act which provided for substantial federal interest-free loans to state forestry organizations for the establishment of the history of Australian forestry. It also marked the recognition at a national political level of a goal of national self-sufficiency in wood products by the year 2000.

Prior to the several years of negotiation which culminated in the enactment of this agreement, the goal of most of the state forestry organizations (which have control of most of the commercial forest on the continent) can be considered as one of forest resource husbandry. The 35 million acres of forest reservations are mostly the residuals of agricultural settlement, and most of the state forest services have had to manage these forests primarily on the income generated. With an average allowable cut of less than 10 cubic feet per acre per year from these native eucalypt forests, this did not allow for much more than extensive management.

In some states, notably South Australia, it was recognized that there were insufficient resources to supply the state's timber needs. Plantation development schemes were instituted, primarily of softwoods and in particular of Radiata or Monterey Pine (*Pinus radiata*). By 1965 this plantation estate had reached a national total of some 650,000 acres. Most of this had been established on land previously administered by the forest services but some acquisition and planting of abandoned agricultural land had been carried out.

Despite this, Australia was still a net importer of wood products with imports amounting to 20-30% of consumption at an annual cost of over $200,000,000 (U. S. equivalent), putting them second only to oil in the list of import items. At this time a newly-created Australian Forestry Council estimated that Australia could achieve self-sufficiency by 2000 AD, by doubling the planting rate to 75,000 acres per year (McGrath, 1965).

Between 1965 and 1970, the state forest services began setting up to meet this challenge. The fact that the millionth acre has now been planted indicates that the rate of 75,000 acres per year is being rapidly approached. This period was also a period of intense planning activity (often under the urgency of political pressure) and it became very obvious that the existing methods of information transfer were inadequate for this suddenly stepped-up organizational activity. It was also obvious that

there were serious gaps in the level of information about the existing and potential resource. This led those engaged in management research in the state forest organizations and the primary industrial forestry company to consider developing computer-based resource information systems which could serve these needs in the future.

Thus MIS development arose out of needs resulting from an increased responsibility and additional goal assumed by the forestry organizations. The fact that this occurred simultaneously in these organizations provided unique opportunities for cooperation and cross-fertilization which have undoubtably hastened the developments.

Because of the intense interest being displayed at the time in softwood plantations, it was natural that attention should be focused initially on the development of information systems which would assist in plantation management. The prototype models were developed by Gibson, Orr and Paine (1969) of the Victorian Forests Commission, and by Dargavel (1969) of A. P. M. Forests Proprietary Limited. Both of these systems were made public at the 1968 Institute of Foresters of Australia Conference and were received with considerable interest by the profession.

Although neither of these systems were claimed to be Management Information Systems, they both were developed with the philosophy of providing managers with information about the plantation resource. Attention was thus focused on setting up adequate systems for data management and information generation and retrieval, rather than on the development of sophisticated growth models.

The data base for both of these systems was a list of stands in the forest together with their ages and acreages and statistics concerning volumes, site indices, size class distributions and so on, derived from the most recent inventory plot information available. This file of stand data was stored on magnetic tape or disc for computer processing and thus constituted as complete a description of the resource as was feasible.

The heart of both systems was the growth projection model. In the case of the Dargavel system this was merely a set of variable density yield tables stored on magnetic disc; the appropriate table was selected by the user depending on the thinning/clear-cutting regime desired for a particular site/density combination. In the Gibson (FORSIM) system growth projection was achieved by sets of equations.

The FORSIM system has two major options (Gibson, Orr and Paine, 1970). The CUTAVAIL option and the Dargavel system both had a similar objective, which was to determine the distributions of volumes from thinning and clear-cut operations over space and time under user-defined management regimes. FORSIM also estimated discounted revenues over the user-defined period of time.

The second option for FORSIM allows the user to specify an allowable cut and set various priorities and other constraints for the sequence of management options. The output from this option is thus an order of working which meets all these constraints.

Both of these systems were able to provide managers with rapid and accurate answers to questions about the management of their plantation resources through a simulation model operating on an inventory data base. Both can therefore be considered as operational, if rudimentary, MIS's.

Since the original promulgation of these systems in 1968 and a stimulating visit from Dr. Gerry Clutter of Georgia in 1969, developments have proceeded in several directions. In the New South Wales Forestry Commission for instance, attention has focused on the construction of a realistic and sophisticated growth simulation model for the principal plantation species, *Pinus radiata*. The model has already been useful in answering specific management questions but has not yet been augmented into MIS. There would be little difficulty, however, in incorporating this model into FORSIM.

The Victorian Forests Commission has followed up FORSIM by switching attention to their major eucalypt species, Mountain Ash (Eucalyptus regnans), and to using an optimization procedure solve the scheduling of cut problem. Victoria has more than 200,000 acres of ash regrowth forest resulting from a disastrous fire in 1939. These stands are now reaching maturity and the MASH system was developed to assist in the planning of the utilization of this valuable resource. "For a given planning period, it defines the schedul of thinning and clearfelling that maximizes the present net worth of the wood resource, subject to various constraints that the manager desires to impose" (Gibson, Opie, and Weir, 1971). The system has four stages described as inventory, stand simulation, product evaluation and parametric linear programming. It can, therefore, be considered as at least a potential Management Information System.

Future Developments and Implementation Problems

Although it may be stretching the definition of an MIS to consider such systems as FORSIM and MASH as complete Management Information Systems, it is apparent that they could provide a strong framework on which to hang such a system. This incremental or evolutionary approach to the development of an MIS is generally favored as being more practical and as making acceptance easier than the total system approach (Schwartz, 1970).

It may be useful to look briefly at some possible avenues for further development. It is apparent that inventory design is going to be strongly influenced by the availability of these information systems. If it can be shown that such systems can provide managers with all the relevant information they want, the inventory must be designed to fill the data bank with the data required by the system. This may well mean that sampling may have to be more intensive than formerly to provide accurate information on a stand basis. However, inventories may be required less frequently than formerly, reliance being put on growth models to keep the data current. This may perhaps be augmented by data collected when the stand condition radically changes as from some silvicultural treatment. This would naturally lead to the inclusion of stand history records in the system.

To take a different tack we might look at the part of the system concerned with the valuation of the resource. If the timber is valued by a residual pricing method (as in MASH), then the marketing manager has a very useful tool for exploring the effects of changes in pricing policies and therefore it would seem reasonable to include the stumpage appraisal sub-system in the system. Since the residual price is dependent on developmental work carried out, in particular roading, a further major augmentation of the system might be the addition of the works and development sub-system.

The potential is great, but are there any factors which might limit such developments, in particular in Australia? The substantial progress to date indicates that there is no lack of technical know how or ability which could limit the expansion of the existing systems. Computing power and storage capacity has slowed down past development, but there are now several large computers in Australia accessible to systems developers. Although some of these computers have time-sharing capabilities, remote terminals outside of the capital cities are not common due to the high cost of long-distance data transmission. This may slow down the process of putting the MIS in the hands of the operations managers, the field foresters.

But until this can be done, any MIS cannot be judged a success. Ultimately, the computer terminal will become as indispensable to the forester as his radio communications equipment and will be treated just as casually.

And just as radio communications had to be sold to the forestry profession, so will computer communications. It is of course essential that management personnel be fully consulted and kept fully informed at all stages of systems development, and training sessions in the use of the system will of course be necessary. But only when the intermediary high priest can be dispensed with, and the manager begins to ask his questions and get his answers, only then will the system begin to work as it should. Anyone who was in on the ground floor when radio was first introduced into forestry organizations should recognize the parallel.

The systems which have been developed in Australia to date have primarily been for the benefit of the planning managers, but quite obviously they could be just as useful to the operations managers. The former, through greater familiarity with the computer, have been less distrustful of these trends toward Management Information Systems, recognizing them not as a threat to their decision-making powers but merely as an extra source of quality information to assist them in making better decisions.

If the developers of these systems want them to be used as Management Information Systems, they will have the responsibility of setting them up so that they can be used from remote terminals by managers, not computer programmers. If top management wishes to encourage this trend, it will have to experiment with remote terminal installations for the field managers. And if the field managers wish to improve their decision-making abilities, they will have to be willing to learn how to use this new and powerful tool.

Literature Cited

1. Dargavel, J.B. 1969. Yield forecasting for industrial plantations. Aust. Forestry 33(3): 153-162.

2. Gibson, B.F., J.E. Opie and I.C.A. Weir. 1971. MASH--A comprehensive system for planning and scheduling regional wood production. Forests Commission of Victoria, Melbourne. (To be published).

3. Gibson, B.F., R.G. Orr and D.W.M. Paine. 1970. FORSIM--A computer program for planning management of even-aged forests. Forests Commission of Victoria, Melbourne. 62 pp.

4. Gibson, B.F., R.G. Orr and D.W.M. Paine. 1969. Improved forest management through operations research. Aust. Forestry 33(2): 111-118.

5. Head, R.V. 1970. The elusive MIS. Datamation 16(10): 22-27.

6. Head, R.V. 1967. Management information systems: a critical appraisal. Datamation 13(5): 22-27.

7. McGrath, K.P. 1965. Approaches to the solution of the problem of future wood supply. Aust. Forestry 29(3): 199-207.

8. Sanders, D.H. 1970. Computers and management. McGraw-Hill Book Co. 458 pp.

9. Schwartz, M.H. 1970. MIS planning. Datamation 16(10): 28-31.

SOLAR, A MANAGEMENT AND EDUCATION TOOL FOR RESEARCH

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Abstract

SOLAR is an information storage and retrieval system developed by Washington State University for the Forest Service with a specific objective, i.e., "to develop a system which will provide relevant scientific and technical information on chemotherapy, of plant disease host-parasite physiology, and biochemical differentiation within host-parasite systems." SOLAR is being utilized to exploit world literature in these fields to develop, refine, and test hypotheses concerning control of disease through manipulation of metabolic events occurring within the *Cronartium*-*Pinus* system.

In order to accomplish these goals SOLAR was designed to provide the user with direct access to and control of the data bank. Thus, rapid output of relevant technical data enables breakdown of broad question queries into multiple, highly specific, subject areas and then provides the means of exploiting each of these subject areas for data which support bases for decisions regarding the ongoing research process.

The data bank for SOLAR contains citations, abstracts and data from each entry in order to provide the technological detail required to ascribe probability parameters for making research decisions. Access to this bank is provided by an open-ended set of terms organized into queries via boolean logic. Terms were provided and tested by plant pathologists knowledgeable in this specialized field.

Copyright laws permitting, SOLAR should be available to interested researchers throughout the country before 1973. A compatible remote terminal and a telephone can provide worldwide access to SOLAR.

A computer based storage and on-line automatic retrieval system (SOLAR) has been developed through a cooperative effort between Washington State University and the U.S.D.A., Forest Service. SOLAR is a functioning system presently being utilized with a search term index and data bank derived to provide technical information regarding plant chemotherapy, plant disease, host-parasite physiology and biochemical differentiation within host-parasite systems. It is, however, adaptable to other types of data banks and term indexes suitable for most areas of technology.

When using SOLAR the searcher communicates with the system via a typewriter-like terminal. The data base, the index, and the searcher are always circuit connected to the central processing unit of the computer. This permits immediate processing of queries. Queries are formulated for SOLAR by the individual searcher. An intermediate search strategist is not required to translate a query into machine coding. Data transmission between the system and the terminal can be accomplished over any public telephone line.

The system data base presently in use consists of document abstracts acquired from two different sources. They are: 1) a private Forest Service collection and 2) the chemical and biological activities (CBAC) magnetic tape service. The latter is purchased from the chemical abstracts service at Ohio State University, Columbus, Ohio. The Forest Service collection was manually selected and includes documents from over 600 different journals and publications. The CBAC magnetic tapes are scanned for documents from 26 periodicals related to plant pathology and continually augment the document store. Both sources are expected to supply a total of 40,000 abstracts before 1975. The full abstract for any item is stored on-line and can be displayed on the searchers terminal. Any single abstract is usually accessible in less than a second.

SOLAR has an open-ended keyword coordinated index. This type of index has the advantage that keywords can be generously assigned to all documents and the searcher need not be concerned about word ordering in a query. SOLAR permits disjunctive searches so if keyword A <u>or</u> keyword B satisfies a query, documents assigned either keyword will be retrieved. In general, the broader the scope of the keyword, or the more keywords used in such a query the more likely an optimal response, in terms of total recall, will be received. For optimal precision, searches using <u>and</u> and <u>butnot</u> connectives are used. <u>Butnot</u> is a SOLAR equivalent to the operator <u>and</u>. The documents containing the <u>butnot</u> word are deleted from

the response listing. For queries using and, all keywords in the query must appear in a document before it is retrieved. Using combinations of the above logic it is simple to formulate queries suitable for posing either broad or restrictive questions to the data base. Recently SOLAR has been adopted to accept free English format for queries. It translates these sentences into the and/or/butnot form automatically prior to searching the data bank. When the searcher feels one keyword is more important than another, he can assign a weight to each term. When term weights are used, they become the primary factor governing the listing of the response. Thus, those items in which weighted terms appear are listed first.

SOLAR turnaround time is relatively unaffected by query complexity. Most query analyses and searches require less than five seconds. Turnaround time is more dependent on the length of response prepared for output. This factor is also under the direct control of the searcher due to SOLAR's output format. At the searcher's disposal, the following options are available for display from all documents selected by the query: 1) none, 2) title, 3) authors, 4) journal, 5) pages, 6) citations 7) text (full abstract), or 8) all of these. Thus, lengthy responses can be restricted to the most successful queries. If desired, hard copy can be requested and the system returned to query mode to proceed with additional queries. The hard copy is mailed to the searcher within a few days.

Browsing is a more subtle type of searcher interaction supported by SOLAR. Here, as in a library, the searcher can scan many titles at his own pace after entering a keyword for a general concept which selects a large number of documents. By selecting appropriate keywords from these documents the searcher can then scan through the term files, which are also available for display, and seek out other related keywords. By so doing, a searcher can achieve substantial technical precision before a query is made.

The user control provided by SOLAR permits a searcher to guide himself through the data bank to obtain only the material that is highly relevant to his interests or, conversely, to discover with a minimum of time and effort that such information is not available in the system. This capability permits multiple searches, each based on the information provided by previous efforts, in short periods of time. By so doing, the searcher can educate himself in areas of technology with which he is not familiar and persue highly restrictive information regarding questions within this technology in a short period of time. Thus, with an adequate data base, SOLAR can provide bases for research management decisions permitting users to preevaluate the potential for success of individual lines of effort on a day to day basis. In the normal course of research such

evaluations are made only on program or project sized efforts and the background information requires many months to collect.

On-line interactive search capabilities in many disciplines could greatly increase research efficiency in those disciplines even though the establishment and maintenance of such systems is costly.

Copyright laws permitting the SOLAR data base presently functioning should be available to interested researchers throughout the country before 1973. The system supporting this data base is adaptable to other types of data resources and is available through Washington State University now.

COMPUTERS AND NATURAL RESOURCES MANAGEMENT
A DEMONSTRATION OF REMOTE COMPUTING CAPABILITIES

John W. Moser, Jr.
Purdue University

An exhibit using live computer terminals to demonstrate computer applications for forestry and related resource management was shown in conjunction with the workshop on Computer and Information Systems in Resource Management Decisions. This educational exhibit provided six remote terminals that accessed, via regular telephone service, several computer installations throughout the United States. These included Control Data Corporation's nationwide KRONOS interactive time-sharing service from Bethesda, Maryland; General Electric's GE-NET international time-sharing system from Cleveland, Ohio; Purdue University's CDC 6500 System; and IBM 360/67 Systems from both The Pennsylvania State University and Washington State University.

The types of terminals that were displayed included Datapoint 3300, Datel Model 30, Execuport 300, Portacom Model PC810 and Teletypewriter Model 33. Printed output was provided by all terminals except the Datapoint 3300 which utilized a cathode ray tube screen for display. All of the terminals were small portable units that may be employed in any office where voice-grade telephone service is available. By simply dialing a telephone number, any of the terminals that were demonstrated may be connected to a central site computer to provide fast, accurate data handling capabilities.

A variety of computer programs developed by resource managers were demonstrated. Applications shown included the following:

PROGRAM DESCRIPTION	SOURCE
Design & Analysis of Furniture	C. A. Eckelman, Purdue Univ.
Edit for Purdue Management Game	T. V. Gemmer, North Carolina State Univ.
Elementary Sampling Methods	J. P. Barrett, Univ. of New Hampshire
File Maintenance	R. Chase, U. S. Forest Service
Fire Control Planning Simulator	R. Chase, U. S. Forest Service
Forest Data Processing Service	J. L. Clutter, University of Georgia
Mill Yard Inventory Simulator	B. B. Bare, Univ. of Washington
Ponderosa Pine Yield Tables	C. A. Myers, U. S. Forest Service
Purdue Forest Management Game	B. B. Bare, Univ. of Washington
Recreation Enterprise Investment Game	P. E. Dress, Pennsylvania State Univ.
Red Pine Silvicultural Simulator	E. F. Bell, Virginia Polytechnic Inst.
Screening in Multiple Regression	W. E. Frayer, Colorado State Univ.
Shadow Pattern Simulator	K. M. Brown, Purdue Univ.
Stand Growth & Analysis	R. A. Leary, U. S. Forest Service
Storage & On-line Automated Information Retrieval	A. E. Harvey, U. S. Forest Service

These programs represent a sample of the large and varied computer applications to natural resources management. They were chosen primarily to demonstrate remote computing capabilities. Most programs that have been developed by educational, governmental and industrial organizations may be adapted, like the above programs, to remote terminal usage as an aid in resource decision-making.

In addition to the programs developed especially for resource managers, an extensive collection of library routines were available for demonstration. These included a broad selection of mathematical routines that are commonly encountered in scientific problems, numerous statistical analysis programs and operations research application programs such as mathematical programming, critical path and simulation systems. Library programs are generally available to all time-sharing users in either binary versions or source versions that may be modified for individual needs.

Remote computing is more than just a simple convenience. Often management personnel in forestry organizations are delegated to regional or district offices with little access to a computer. Remote terminals open new possibilities. They allow the manager to interact directly with a computer from his desk. The almost instantaneous response allows the user to feel as though he alone commands the computer. He may create, edit, debug and execute programs to assist in reaching logical, intelligent management decisions with a minimal expenditure of time and money. Further, such a system makes it possible for several managers at remote locations to interact with one another through the computer, drawing on its large library of data and programs and its speed as they do so.

This exhibit was cooperatively sponsored by Control Data Corporation, Forest Service - U.S. Department of Agriculture, Pennsylvania State University, Purdue University, Society of American Foresters and University of Washington.